COTTON CULTIVATION

IN ITS VARIOUS DETAILS,

THE BARRAGE OF GREAT RIVERS,

AND

INSTRUCTIONS FOR IRRIGATING, EMBANKING, DRAINING, AND TILLING
LAND IN TROPICAL AND OTHER COUNTRIES POSSESSING
HIGH THERMOMATIC TEMPERATURES,

ESPECIALLY ADAPTED TO THE

IMPROVEMENTS OF THE CULTURAL SOILS OF INDIA.

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PREFACE.

THE information which will be found in the following pages respecting the cultivation of cotton, especially in India and Egypt, is derived from reports made by me about three years since; the groundwork of these reports being based on practical knowledge, experience, and an extended acquaintance with countries which have been inspected and surveyed, with a view of introducing systems of adequate cultivation and other improvements connected with extensive works of irrigation.

These undertakings were designed principally with a view of improving and extending tropical culture, together with the erection of such engineering works as precede and are connected with the operations of irrigation. The attainment of new sources of cotton-supply required by the various manufacturers of Europe would by these means have been materially advanced. The war between France and Austria at that time interposed obstacles to the further prosecution of these undertakings; consequently the subject was not pursued. A further delay, it is believed, was caused by the existence of a supposition which more or less did, and even now holds ground, that the unfortunate and disastrous war which afflicts the various States of America is supposed to be in a probable way of being brought to an immediate and final close; but, unhappily, this favourable view of the question has no prospect of realisation.

The various divisions of the work have relation to the improvements essentially necessary for tropical and semi-tropical cultivation; the instructions given are based on a long practice relative to the indrainage of land and the application of water to the purposes of cultivation in countries where protracted rainless seasons annually occur.

I should have been cautious in venturing to recommend the construction and application of barrage to great tropical rivers as a means of at once ameliorating and agriculturally improving districts of country of an extent almost limitless; but having studied the periodic condition of these rivers in the countries through which some of them flow, and having had experience in the construction of hydraulic works connected with agriculture as large as those proposed for the barrage of tropical rivers, I feel no hesitation in stating that barrage will be mechanically and physically practicable. Much profit will be derived from their application, and I am certain they will be the means of rendering the whole extent of country as far as their aqueous influence extends, agriculturally fertile and commercially prosperous.

The details respecting tropical agriculture are derived from practical observations, data, and experience; and, as far as possible, are freed from professional technicality; and it is hoped the subjects will be readily understood and the instructions easily applied.

I must take this opportunity of thanking Henry Princep, Esq., Member of the Council of India, for the valuable information he is, from his experience of all that concerns that country, so ably qualified to give, and which he has always been ready to afford me, especially in respect to questions relating to the growth of cotton and the production of salt; two questions intimately connected with the reclamation of land, as will be seen in the reports.

I have been expecting to see from some official quarter the publication and diffusion of practical directions especially applicable to the growth and production of cotton in Egypt, India, and other places, to be announced; but I am not aware that any detailed system of tropical culture has yet been sent forth to assist in the present emergency. Therefore, but not without considerable reluctance at putting myself so prominently forward, I offer all the knowledge bearing on this important question which

I possess; and although the technical language of an engineer may not be interesting to read, yet I prefer that the reports should be given exactly as they were written, rather than have the advantage of any extraneous literary polish.

Although the primary object of publishing the information contained in these reports is to further the interests connected with cotton culture and the attainment of several sources for the necessary supply of that indispenable article of commerce, yet the improvements in cultivation recommended are equally available for the production of all agricultural crops grown in tropical and other countries where there is a deficiency of rainfall, and seasons and periods of great heat occurring at the same time.

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CULTIVATION
OF
COTTON IN INDIA
AND OTHER COUNTRIES.

CHAPTER I.

GENERAL REMARKS ON THE COUNTRIES CAPABLE OF GROWING COTTON.

THE regular supply of cotton for the manufactories, not of England alone, but for those of France, Germany, and the rest of Europe, becomes a question, not only of vast importance, but of imperative necessity, at this particular period.

My practical acquaintance with the nature and growth of the cotton-plant extends over a period of more than forty years. Having been much engaged in large drainage works, I have paid great attention to the capabilities of several countries, by irrigation, to produce cotton, more especially in districts and lands now entirely unused for cultivation.

It will be well to premise the following observations by stating that most of the lands which will have to be alluded to hereafter as capable of growing cotton, have been examined by me, and some of them with great minuteness, and accurate surveys made thereof, with a view of bringing such lands into cultivation.

These countries are comprised in the following list:

1st. The coast of British and Dutch Guiana and French Cayenne, the island of Jamaica, and the Bahamas.
2nd. The coast of the Mediterranean along the Gulf of Comachio.
3rd. Egypt.
4th. Asia Minor near Tersoos (Ancient Tarsus), and other parts of the Ottoman Empire.
5th. The east coast of Ceylon.
6th. India.
7th. Madras, and along the Bay of Bengal, and in the other parts of India.
8th. Australia, and the north island of New Zealand.

The whole of the lands here spoken of are situated near, and influenced by, their contiguity to the sea, which undoubtedly exercises a beneficial effect on the quality and quantity of the cotton grown.

AS TO THE GUIANA AND CAYENNE COAST, AND THE ISLAND OF JAMAICA.

There are large tracts of rich land in British Guiana bordering on the sea-coast, which, when put into cultivable shape, have a constant supply of water derived from the interior for moistening at all times the root of the plant, and the capability of yielding an immense amount of produce; and by the use of the system of irrigation and cultivation, which will be hereafter alluded to and described, there will be a very large and constant crop ensured; but at present, from the deficiency of labour, not much cotton is grown on this coast.

The cotton already grown on this coast, and in the island of Jamaica, is of a valuable character, and plentiful in yield from a given surface of ground.

In the island of Jamaica there are great tracts of lagoons, and oozy land, and swamp, near the sea-coast, which not only are at present useless, but are in the extreme pestiferous, from the stagnant state of the water which covers these marshes and lagoons. To lower the water-level of these lands would be neither difficult nor expensive. The lands so reclaimed would be most valuable for cotton cultivation, and water being made to constantly circulate through the irrigating canals would restore the salubrity of the air, and at the same time ensure in the dry season the adequate amount of moisture to the growing plants. But there are uplands in Jamaica capable of being irrigated which will bear crops of fine cotton; and from the proximity to the sea, these lands will always be receiving the benefit of the equable marine climate, so essential to the growth of a good cotton. But for large and certain results, at small expense of labour, the drained grounds before alluded to, when bounded by canals, would produce the best crop, and that with less expenditure of capital than the uplands here referred to.

THE COAST OF THE MEDITERRANEAN AND ALONG THE COMACHIO NORTH OF RAVENNA.

On that part of the Italian coast, which until recently was called the States of the Church, there are large tracts of wild unreclaimed swampy land, not only useless, but rendering the country unwholesome from malaria. This district now belongs to the kingdom of Italy, and should the political aspect become calmer, a complete region of productive land of the richest quality, capable of being supplied through the excessive heats of summer with water from the river Po, may be reclaimed, and, by the aid of mechanical appliances, rendered useful for the production of cotton, benefiting to a large extent an almost unemployed population.

The same description of land extends along the sea-coast through the Venetian territory, almost as far as

Trieste. These lands have at all times been in the same state of uselessness, because at one period of the year the floods from the interior, together with the rains, cause them to be either wholly or partially submerged, whilst the abundant vegetable matter which decays during the great heats of summer causes the atmosphere to be charged with malaria, added to which, the want of tide in the Mediterranean Sea renders efficient drainage by cutting channels and sluices impossible, and the feasibility of artificial drainage by steam (so valuable in Holland) has not yet been contemplated in these territories; but if steam drainage is resorted to as a means of bringing these tracts of waste into profitable use, the best results will be realised, if combined with a system of barrage applied to the great rivers to assist the operations of irrigation.

ASIA MINOR, EUROPEAN TURKEY, GREECE, AND THE GREEK ISLANDS.

There is a considerable quantity of cotton grown already in Asia Minor, but the most available lands, and those which would produce the most certain and abundant crop of superior quality to any now grown in the territory, would be reclaimed from the now useless swamps which so frequently occur on the coast of that country; but, from personal inspection, I am only able to speak to lands in the neighbourhood of Ancient Tarsus and the coast of Salonica.

Here a prodigious quantity of land is periodically covered with water during the rainy season, and is again dry in the hot season, thereby causing most dangerous miasmas, but which the most insignificant and inexpensive works would entirely obviate, and render a rich tract of country available for cotton-growing without the chance of failure, inasmuch as the canals which would divide the plantations would have circulating through them living water at a level at all times adequate to the growth of the plant; and as the people of the country are not only capable of carrying on cultivation, but are desirous of doing so provided their rights and property are respected, there can be no doubt but this would become an important cotton district, provided proper treaties can be effected with the government of the Ottoman Empire for the possession of the land. In addition to these swamps, there is also an extensive tract of country to the west of Tarsus, extending as far as Salifka, in which country there were ancient olive groves, the traces of which are now mixed with wild foliage; but the land is capable of cultivation for cotton if irrigated in the manner which will be hereafter described.

The shipping port of the district should be transferred to Messina, twenty miles to the west of Tarsus, provided a canal be constructed over the level countries between the two towns, and which canal might be extended north-east as far as Adanah. This canal in its lower part would not only serve for the navigation of the country, but would at the same time be the great irrigating canal for supplying sweet water to the lands I have before referred to.

The river which runs by Tarsus is the Cydmis, which rises in the Bulgha Tag and Allat Tag; but there is another river parallel to the Cydmis, called the Saltherm, which rises from the Tarsus mountains.

This river at Tarsus nearly joins the Cydmis, and both together, if impounding reservoirs were constructed in the upper countries, would irrigate eighty thousand acres of land, which quantity exists within their influence; and with this constant supply of water, coupled with the fineness of the climate, magnificent crops of corn and cotton could always be ensured.

The district round Smyrna is the most noted cotton-producing part of Turkey, the plantations being chiefly situated on the plains of rising grounds which lie parallel to the river Meander and other rivers descending from the great chain of the Sultan Dagh. In ancient days, the country round Smyrna was noted for its cotton wool, which for particular uses is now unequalled by any other description of fibre. Like all the rivers in Asia Minor, the Meander and its tributaries are liable to floods; and there are periods of dry weather when the use of impounded water in the upper levels or tributaries would be of the greatest value to the agricultural interests. But, unfortunately, export duty and tithe amount to twenty-two per cent. on the value. This immense charge and the uncertain tenure of the land conjointly prevent that spirit of industry and enterprise so essential to progressive improvement from developing itself in this fine country. But it is the opinion of Mr. Crampton, the civil engineer employed on the very difficult task of constructing the railway from Smyrna to Aden, and Mr. Hyde Clark, also connected with the direction and management of this railway, that very great improvements can be introduced into this country with advantage for furthering to a very large amount the increase of cotton and flax cultivation, not only in the valley of the Meander, but also along the whole district occupied and intersected by the Aden Railway; and, without doubt, there is no soil more favoured by nature and situation than this is in the Ottoman Empire, and especially in reference to having the means of transporting its produce from a distance so far inland and to so good a port as Smyrna. The introduction of railways will be the means of breaking through the prejudices of the ancient system of cultivation, and placing its industrial operations in a state more analogous to the modern practice of agriculture.

In other parts of Asia Minor cotton is grown, but its culture and quality might be greatly improved and extended by draining the land on the sea-coast, and then irrigating it by the neighbouring streams. The country most worthy of attention, perhaps, in any part of the Ottoman Empire, and most capable of extensive improvement both as regards cotton and most other agricultural productions, is situated on the sea-coast and neighbouring uplands, from the Gulf of Saros, on the east, to the Gulf of Salonica, on the west, comprising the coast of Roumelia, in European Turkey. All the rivers in this territory rise from the great mountain ranges of the north, being a continuation of the Balkan chain. These waters bring vast accumulations of alluvial matter, which, although forming a rich soil, nevertheless has choked up the mouths of the rivers. The sea-coast is extending through these accumulations, and great swamps and morassy grounds remain, contaminating the air along the greater part of the shore, which is but thinly peopled, and in many parts entirely uninhabited. These territories possess a magnificent climate, and a capability for productiveness, which, if in the hands of a race of Hollanders, would have manufactured wealth by tillage, and thereby have supported a population of unlimited extent.

The neighbouring upland is more cultivated; yet, having regard to the natural fertility of the soil, this fine country may be considered as still in a state of nature, both as regards tillage and intercommunication.

EGYPT.

This country already produces, by the aid of Arab cultivation, a considerable quantity of cotton of very fair quality, and of a yield nearly equal to that of the

American plantations, acre per acre, but the total quantity produced is insignificant as compared to the total extent of the country capable of bearing cotton crop.

It is well known that the lands of Egypt are at all times ready, without any other previous preparation than that of the plough or hoe, to receive seed, and, by application of Nile water, either flowing upon it continuously during high Nile, or lifted upon it by mechanical means during low Nile, to yield every description of crop applicable to the climate, without the aid of manure or of further cultivation than that of preparing the land to receive the seed. Along the sea-coast from the desert of Ammon, on the west, nearly to El Arish, on the east, there are large salt lagoons of shallow depth, nearly drying out at low Nile, the lands of which lagoons are composed of the richest soil, easily freed from salt by irrigation, capable of producing vast crops of cotton and flax. The climate is so equable, the supply of water may be made so constant, that the production of cotton would be of the heaviest, and the certainty of the crop would almost always be secure.

In addition to these lagoons, there are great tracts of available land not only in their immediate vicinity, but in all parts of the Delta of Egypt, slightly remote from water, and which lands are now entirely uncultivated.

The general impression is that nearly all the available land in Egypt is now under cultivation, but this opinion is erroneous, inasmuch as tillage merely follows the banks of the rivers and canals, the rest of the country lying in a state ready to give, with the application of water, a crop without other preparation than that of merely ploughing. The country is entirely flat, not a single knoll or hill existing in the whole Delta except such mounds as indicate the site of ancient and deserted towns. Irrigating canals could be introduced in all directions to put the unoccupied land into beneficial cultivation, and there is no country where agriculture could be carried out so inexpensively as in Egypt. At present all the cultivation is similar to that practised in the time of the Pharaohs—except on one or two model farms belonging to the Pachas—no improvement has taken place; even there the agriculture is rude, and in a great measure carried on the ancient system of cultivation.

I have examined the whole of the Delta from Cairo to the seaboard, and all the branches of the Nile and the canals leading from it, and in some cases have made minute surveys of the country, and I can state that at least one million five hundred thousand acres of land now unoccupied could at once be put under crop for cotton, thereby extending the useful area of the country to that extent.

It has before been stated that the cultivated land of the Delta of Egypt is situated along either the banks of the two branches of the Nile, or along some of the canals which derive their supply of water from that river, all the rest of the Delta country being level desert, without habitation, tree, or shrub. The only vegetable productions which cover the ground are saline plants, indicating that in every part of that country a more than usual quantity of salts are present in the soil, and undoubtedly contribute to its fertility.

All this uncultivated land is below the level of high Nile, and is as capable of being watered as the now occupied portions of Egypt are; but this vast waste has either lost its inhabitants, and therefore ceased to be watered, or is in the state nature has left it. An examination of the country, however, shows that both these circumstances have contributed to bring or keep so large and so valuable a portion of the country uncultivated. Any part of this land is capable of growing one crop of cotton, or one crop of flax and one crop of corn (dura) per annum, or, with sufficient water, six green crops of Egyptian clover may be grown in the same period.

Above and south of Cairo the lands which border upon the Nile are called the Saied, in contradistinction of Lower Egypt or the Delta. A considerable portion of this land, which lies under the high-water level of the Nile, is very productive, and when the water from low Nile is lifted up by saggar, chadoofs, or other hydraulic appliances, and spread over the ground, valuable crops were raised after seed-time, without further expense beyond the cost of lifting the water. This is accomplished by human labour to work the chadoof, or oxen, horses, or buffaloes to work the saggar or lifting water-wheel. The high ground of the Arabian and Lybian deserts often approach so near each other that the cultivated land—that is to say, the land limited to overflow—becomes so narrow that no great scope exists for the operation of any combined works of irrigation, if of an extensive character; but at Beni-Souef the Nile valley widens out on the Lybian side to a vast extent, and forms the Fayium, on the north-east side of which is situated the Berket el Korn, being the receptacle for the extra overflow water from the lands lying below the Nile and above this lake. This division of the country was in ancient times celebrated for its productiveness, and for its equally celebrated lake of Moeris.

This lake undoubtedly was a high-level reservoir, constructed in such a manner that the water of the Nile could be diverted from its natural course (by the ancient canal of Youseph) at a point much higher up the stream, by which means large tracts, never reached now by the Nile, were then in the full vigour of productiveness; and from the fact that the lands of the Fayium slope to the west towards Lake Korn, and to a depth much below the level of the bed of the Nile, it follows that by a scientific arrangement the water conduction to the lands could have been effected after the Nile level had sunk below its ordinary available point; and further, the dykes (the remains of which are still large and visible) would have shut off the flood-water from uselessly flowing without control towards, and year by year filling, the lake, or Berket el Korn, the water of which was, and is now, evaporated by solar heat, of course leaving the water in the lake and much of the neighbouring land in a very saline state.

There can be no doubt but that water arrangement was well understood in the time of the Pharaohs, and was acted upon as above described in this celebrated spot, as far as the available appliances of that period would admit of, and that a large portion of the area of Lake Korn was cultivated; because if the water was admitted in the district only for cultivation, and was used without waste, the lake would dry up in two or three years, leaving only a small receptacle in its deepest part for salt water to lodge in. This receptacle will always be salt, because of the great evaporation which takes place. If the works were now restored on a good principle—if a barrage was constructed higher up the stream, and a high-level irrigating canal was conducted therefrom into the Fayium—not only would the value of the present imperfectly-tilled lands be greatly increased, but six or seven hundred thousand acres (English) would be added to the cultivated area of the country, of a quality inferior to no other land, and capable, from its peculiar local features and beautiful climate, of growing three agricultural crops per annum, or one crop of flax and one of cotton each year without any application of manure whatever.

Along the north-west foot of the Mokattam hills, north-west from Cairo, passing through the valley where the ancient canal took its course, from the Nile towards Suez, there are great indications, when pits are sunk, of a copious supply of sweet water being in existence. The soil on the level plain is of a very superior character, and by the expenditure of a little labour this wilderness could be reclaimed and made to produce fine crops of cotton, corn, sugar, or other produce; whilst the height of the lift of water, and consequent expenditure of mechanical power for irrigation purposes, will be very little; but how far such cultivation might interfere with the proposal of M. Lesseps to take sweet water from the Nile to his canal I am unable to say. It is, however, probable that M. Lesseps will claim all this land as appertaining in some way or other to his great undertaking; nevertheless, I apprehend there will be little difficulty, by proper treaty, of bringing this desirable tract of country into a state of productiveness.

In reference to practical cultivation, it may be said that in Egypt there are no ploughs, properly so understood, except such as were used in the time of the Pharaohs, and which consist of a great beam of wood with one upright handle, and a wooden shoe to tear up the ground, which is only done in alternate furrows, leaving one-half altogether unploughed; after which, the land is cross-ploughed again in the same manner. This leaves altogether one-fourth of the ground undisturbed—the rest remains in an exceedingly rude state; but by the application of the water of the high Nile, or water lifted on to the ground artificially, the clods are turned into mud, and after being levelled with a beam of wood drawn across the ground instead of harrows by two oxen or buffaloes, the seeds are cast on the soil, and the beam being then again drawn over the surface, covers them, and then the farmer's duty is considered to be ended (with the exception of applying irrigating water) until the crop is ready for gathering.

The wheat, bean, and clover crops are cut by an Arab whilst he is sitting on his heels, and in that position he uses a sickle about as large as a countryman's ordinary pocket-knife; the women then carry the product to the thrashing-floor, but which is an improper term, inasmuch as there are no barns, flails, or appliances for thrashing either in Egypt or Syria, grain being invariably trod out by cattle on floors of earth, and in the open air, and is sifted by being cast before the wind to carry off the chaff. The spade is unknown, a short-handled heavy hoe being the only manual instrument with which to dig or stir the earth. There are no barns, thrashing-mills, implements, or wheel-carriages; and, except for the growth of melons, grapes, culinary vegetables, and oranges, no manure, except that derived from the pigeon, is used. These remarks are made to show how little Egypt is indebted to the labour of man for her fruitfulness. It is the level surface of the country, the uniform character and richness of the soil, the facility of spreading over the whole Delta the waters of the Nile, when these waters so undeviatingly rise to the destined level, together with the capability of the climate every day to forward the plant to its maturity, that we must regard as the principal cause why this favoured country should at all times have been so celebrated for its vegetable wealth, not only supplying its own wants, but also leaving a vast amount to be exported to other countries. If, then, so large a produce can be obtained by such little effort, what might we not expect to obtain by the introduction of proper systems—the improved application of water distributed by new hydraulic arrangement, together with the use of the steam plough for bringing the vast tracts now idle into perfect cultivation and profitable usefulness? and nothing could lead to this desirable result more than the growth of cotton on a considerable portion of this unemployed territory.

It has been thought necessary to dwell on this part of the question at some length, because it must be remembered that Egypt is only eight days' journey from London, and that, supposing land is obtained by treaty, it would be under constant supervision and attention by Europeans. The climate is a perpetual summer, and every day a growing day. By the application of water a full crop is ensured, and the facility for shipment of product very great, and the people are docile. Great freedom is conceded to Europeans. A most intelligent Christian population exists, and no religious or other prejudices are allowed to interpose to prevent European enterprise being carried out. All these considerations weigh much in favour of forming an establishment for the growth of cotton in this country, not (be it understood) to the exclusion of similar efforts being made in other countries, it being obviously necessary to extend our demand for the growth of that staple to several important sources of supply, and by that means increasing our intercourse with many countries.

CEYLON.

Along the coast of Ceylon there are lagoons of shallow depth, not difficult to drain and afterwards to irrigate. Contiguous to and joining these lagoons are vast tracts of low swamp and jungle. The drainage of the lagoons would reclaim the swamp and jungle above alluded to, and, as there are copious streams contiguous to, and available for, irrigation, much cotton ground could be laid out of great value and productiveness; and, although the native population is small compared to the extent of country, employment would attract persons from South India, China, &c., to locate on lands which are now valueless. If the great tanks were repaired and made available for this purpose, much ground now entirely deserted would be restored to that state of fertility which once undoubtedly possessed.

NORTH AUSTRALIA.

In North Australia, and on the east coast as near as Melbourne, but farther to the north, there are large tracts of land nearly to the level of, and, in some cases, a little below, high-water mark. These lands (more or less saline) are composed of extremely rich soil, and would undoubtedly grow cotton; but frequently there is for a long period a total absence of rain, therefore, without irrigation, cultivation would be very uncertain. Most of these swampy lands are situate within the influence of, and are frequently caused by, contiguous rivers, having either choked outlets or sand bars at their entrances; but the absence of population necessary for cultivating cotton, or other like crops, on a large scale, would be a great drawback in this country to an enterprise of this description. Probably, by the introduction of Coolie labour, this difficulty might be removed; still it does not hold out the great advantages we find in other countries, except so far as that of its being entirely an English colony, and possessing along the sea-shores a magnificent and healthy climate and rich land well adapted, with irrigation, for cotton or other culture.

NEW ZEALAND.

On the north island of New Zealand cotton could be grown as an annual on what are termed the flax swamps, which are capable of being at a small cost drained and properly laid out in plantations; but the cost of labour is so high, that, without the importation of labour cheaper than that of either native or European, no good result could be arrived at. But, to show the effect of the equable climate, it will be sufficient to state, that I have seen the rose and other tender plants in full bloom and growth during the winter; and as regards the native flax as a fibrous product I shall have occasion to speak of it hereafter.

INDIA (MADRAS, BOMBAY, AND BENGAL).

Along the sea-coast of some parts of Madras and Bengal there are extensive tracts of low-lying ground, sometimes covered with water by the high tides, and frequently left dry for a considerable time. These grounds are mostly below the level of the neighbouring rivers, the water of which would be diverted by irrigating canals in such a manner as to keep the land always moist; and as these lands are most frequently level, the water in the canals could be maintained at the exact altitude which neither swamps the ground nor allows the growing plant to suffer in the dry season for want of sufficient moisture. This arrangement is of great consequence, not only in this but all other countries, to ensure the quality and quantity of the crop of cotton regularly every successive year.

There are, besides, other level lands having water upon them during the rainy season which could be embanked and drained, and would also have the great advantages of perfect sub-irrigation by canals, as will be afterwards alluded to, the water being derived from the higher levels of the neighbouring rivers.

The lower lands are of vast extent, and are now agriculturally valueless. It has been imagined that they were not in any way worth cultivating: first, because they contain more or less saline matter; and next, they would require an outlay for draining and laying on the water. But the fact is, these Indian lands, so situated near the sea, have the command of water by a limited outlay, and if treated in the manner hereafter described, are perhaps the most valuable lands in the country.

Farther inland there are other great tracts of country, on rather higher levels, also valuable for cotton growing, and nearly free from saline matter, on which land irrigating water could be mechanically lifted, during the dry season, with great facility, and distributed over the surface by canals or other artificial means. But whether cultivating the inland soil, or that along and near the sea-coast, it is indispensable that the supply of water for irrigation during the dry season be not only copious and equal to evaporation, but that adequate engineering arrangements should be made for so applying it to the soil at all times, and in such a manner, as to ensure the highest quality and largest amount of vegetable production.

Of course, in discussions having reference to India, it is useless to state the amount of acreage available for the growth of cotton, because by the cultivation of the vast extent of surface of even that description of land just spoken of, the present amount of supply of cotton from all parts of the world could be doubled from India alone, if that proceeding was deemed advisable or necessary. The amount of cotton which may be grown is only a question of capital, combined with the exercise of judgment in expending that capital, together with the introduction of those mechanical agencies to abridge labour so well understood in this country.

It may, however, be stated, that along the coast from Cape Comorin, latitude 8 deg. north, to the northern Circars, following the coast by the great Chilca Lake as far north as Ballasore, latitude 2 deg. 30 min., there are lands more or less capable of cultivation for cotton, with the advantage of contiguity to the sea, and within reach of sweet water for irrigation. These lands cannot, after excluding waste, be less than eight hundred miles in length, may average ten wide, and similar in most respects to the American and West Indian cotton coast, only differing from that coast in respect to rainfall, which is more periodic than in America, and which is the great drawback to the growth of cotton in India. This drawback may, however, be remedied by draining and irrigation; increase of produce may be obtained by deep ploughing; and it is not excessive to state that five million of acres along the east coast of the peninsula alone might be brought into cultivation for alternate crops of cotton, flax, and corn.

The river Indus, in its upper levels, affords vast scope for improvements, by the introduction of perfect systems of irrigation, more especially in the districts of the Punjab, Lahore, and Scinde. Diversions of the river might be available for supplying water to countries towards the south-west, to a degree only limited by the volume of water flowing down the Indus and its affluents. But these improvements for governing the waters of rivers must, from their bearing and importance, be treated of separately, and will be found under "Considerations relative to Barrages of Rivers;" these considerations being applicable to all rivers liable to lose their depth of flow during periodic dry seasons. To return to the question of the improvements to be effected in the Punjab, Lahore, and Scinde, it appears that the capabilities of these territories are so very great in respect to the increase of agricultural production generally, that if the land is once irrigated in a proper manner much more valuable crops than that of cotton would be raised, and this plant would only be put in the ground as a periodical alternative, after the cultivators have learned the value of, and introduced into their husbandry the system of, rotation. Perhaps, therefore, for these considerations, too much dependence should not be placed on these countries for a permanent part of the supply of cotton, but to look more especially to the advantage of irrigation for all crops generally produced in this climate, as well as that of cotton.

The deltas of the Indus claim especial attention, because of their great similarity to those of Egypt, from which they only differ in respect to some inconsiderable amount of rain which periodically falls upon them, and also from their less capability of self-irrigation as compared with the Delta of the Nile.

By the application of barrage to the river Indus, by the introduction of high level canals for distributing water over the country, and by the creation of canals for taking off the superfluous water, the Delta would at once become fertile and healthy; and as the soil is as rich as the Delta land of Egypt, it would make a return in agricultural productions as great as is obtained from the same area in that country. As respects labour, both the Delta of the Indus, the other parts of Scinde, and the Punjab, possess a much more numerous population, on a given space, free from the prejudice of caste, and in all respects equal to, and perhaps more fitted for tillage labour than the Delta of Egypt. All that is required to convert this Delta into valuable healthy property is drainage and irrigation.

The presidency of Bombay has long been celebrated for its cotton production, and perhaps here the cultivation of this plant approaches nearest to that of a system than exists in any other part of India. The centre of production being the Surat and the

Broach districts, the many fine rivers of this territory so well fitted for irrigation, the richness of the soil and agricultural fitness for easy tillage, its contiguity to the sea and the consequent equability of atmosphere, point out this part of India as most adapted to enter into the contest of commercial competition with other countries in the production of cotton.

The lands near the sea-coast, from their low-lying positions, would be easily irrigated, and large tracts, at small expense, could be reclaimed from tidal overflow; the rivers, by comparison, are not large, and could be dealt with so as to divert some of their waters for agricultural use. The lower gorges of the neighbouring mountains afford sites for impounding reservoirs, so as to maintain the constant flow of every stream.

All these conditions are requisite to the due attainment of perfect cultivation, for in this, as well as in other parts of India, there are periods of considerable duration, annually occurring, when the evaporation is so greatly in excess of rainfall, that at such periods the artificial flow of water derivable from rivers is the only resource for continuing the growth of plants.

If we look at the geographical position of the cotton-growing countries generally, it will be found that those which yield the greatest amount of commercial produce are mostly situated on an eastern coast, or on other coasts where the gentle winds set in from the sea; and that saline soils and sea-breezes greatly influence the length of staple, the quantity of product, and the certainty of crop; experience also shows that too great an exhaustion of moisture from the soil injures the leaf, and consequently entices insects to attack the plant; that too large an amount of water swamps the ground, stays the growth, and injures the vegetation, but that moisture drawn upwards to the plants, by capillary attraction alone, will keep the plant in vigour. Now, on both the east and west coasts of the peninsula of India the power of bringing all these requisite conditions into operation exists; but unfortunately, with a tropical climate, without capital, with most limited observation, and strong prejudices to obstruct their perceptions, the native population of this country are incapable individually, and unwilling collectively, to adopt any systematic mode of culture by the combined operations of many, so as to irrigate the land, or to introduce superior methods of raising the produce; therefore nothing will be done to increase either the cotton or other crops in India, unless some comprehensive system is adopted at home to irrigate by canals, and by other means conjunctively, to prepare the land by the intersection of minor water-courses, to supervise the application of water, to effect the deep and first ploughing by mechanical means, and to clean and pack the cotton when the crop is ripe. If all these be done in a proper manner the natives will accomplish the rest; and at a future time, when they have had experience of the profits derivable from the new system, they will—except that of the hydraulic administration — undertake all or most of the operations themselves.

Some of the preceding remarks are justified, in a considerable degree, by the perusal of an elaborate and most able work on the growth of cotton in India by Dr. Royle, which work faithfully describes all the difficulties of dealing with a hot and unequal climate, and where no means of supplying the deficiencies of rainfall by irrigation have been introduced. In that work will be found an account of some valuable experiments, on a large scale, by Mr. David Lees, of Manchester. These gentlemen, in the work alluded to, frequently draw attention to the difficulty existing in India of suppressing the excessive growth of wood, whereby the crop is limited in quantity. Now, in regard to irrigation, we have all through this paper been advocating its adoption; and in respect to the overgrowth of wood pruning will remedy that; but if deep ploughing, especially by steam, be resorted to (say two feet, or two feet three inches deep), the heavy rains soaking through the soil in the wet season, and capillary action of the soil in the dry season, will cause the roots of the plant to spread throughout the soil to the depth of the ploughing, and the yield of cotton will be as great as the ground can carry, by reason of the superior size of the root, induced by the deeper till of soil, and a just proportion will be maintained between the wood and the fruit.

That vast crops of cotton may be grown in India by irrigation, if properly applied, is proved by what is done in Egypt, where there is no rainfall at a short distance from the coast, and even there only a few showers occur in the winter season; therefore in that country all is dependent on the artificial applications of water, and the natural good quality of the soil and climate. Now in Egypt at least three times as much cotton is obtained per acre as is obtained in India; nevertheless, if in Egypt, by the introduction of deep steam ploughing, and by the use of more perfectly-formed irrigating canals, greatly increased crops may be still further obtained, and if the full crop due to the land and climate of India, by improved means, should be in like manner arrived at, that is to say, four hundred or five hundred pounds of clean cotton per acre, instead of from forty to one hundred pounds as at present (and that without much more expenditure of capital), how vastly then would the revenue of India be increased, the resources of England for self-supply be ensured, and the anxieties respecting the production of cotton would for ever cease.

It will be seen, from what has been already stated, that the low-lying grounds near the sea-coast having a facility of irrigation, and having, to a certain extent, saline properties in the soil, are selected, in preference to all others, for the growth of cotton.

This preference is due to the superior productiveness of, and the quality naturally belonging to, lands so situated; and there can be no doubt but that a certain amount of saline matter, together with the proper degree of moisture in the soil, from the time the seed is put into the ground until the cotton crop is gathered, is essential to the attainment of quantity and quality. Experience also shows that alluvial soils, of moderate texture, are the best for the moisture to percolate through during heavy rains, and in such a soil the root of the plant can expand in all directions if properly and deeply tilled, besides obtaining at the same time the advantage to be derived from an equal admixture of, and distribution in, the soil, and in the water of irrigation of the materials of sustentation required by plants, and which circumstance must at all times be kept constantly in view.

A large portion of the lands alluded to in this paper are of the description here recommended.

CHAPTER II.

MODE OF CARRYING OUT A PLAN FOR PROMOTING THE CULTIVATION OF COTTON, AND OTHER AGRICULTURAL PRODUCE, IN INDIA.

In Holland and in the Low Countries the proper administration of water-flow is so indispensable to the prosperity of the states, and as it is well known that no yield from the land would be obtained unless the water is most carefully directed both for drainage in wet and for supply in dry weather (through the capillary attraction of the soil), that there is in consequence established in those countries a most important division of the government called the "Waterstaat," to whom is entrusted the regulation and working of all outfalls and drainages, also all decidings on the heights of water-surfaces and levels at different seasons of the year, the direction of the innumerable canals consequent on the nature of the particular system of cultivation adopted in these countries, and the demand for inland communication, together with all other matters regarding the inlets, outlets, and the general circulation of water.

Now, by the skill and experience of such departments, and their perfect organisation, the lands of these territories, after supplying dense populations, are capable of furnishing for export a considerable amount of agricultural produce, and by means of perfect cultivation there is more wealth distributed amongst the people than is found to be the case in any other country; the lands are better tilled, and perhaps a greater population is maintained on a given cultivated surface than can be found to be the case in any part of the world. If such a system answers so well in territories which would but for its water arrangements revert back to the original state of swamp and fen, how much better would a water system work in India, where, during most part of the dry season, the cereals and grasses cease to grow, and whilst the monsoon rains fall the country is inundated by a superfluity of water. It is not to be imagined that any great system can at once be initiated in India, but its principles might be adopted to a certain extent, and by a graduated process it might, in a limited time, be applied at least to all the extensive and low-lying districts of that country.

It would not, perhaps, be possible to create such a department as exists in Holland entirely belonging to the government, nor would the public feel satisfied to supply capital to a commercial company assuming the powers on so vast a scale as to cultivate lands in India for all the cotton and other crops which it is capable of producing; but a company approved of, and co-operating with a government department constituted for this purpose, asking for capital to be applied to the especial purpose of irrigation and preparatory cultivation only (the proceeds, after paying expenditure, to form dividends), would, as a natural consequence, obtain the necessary funds for carrying into effect drainage, irrigation, preparatory cultivation, and canalisation; but it would be indispensable that capital should at all times be adequately represented, or a company could be formed in which a perfect supervisal of the administration by the government could be maintained, so that such company would not be permitted to diverge from the legitimate object for which it was established; and most likely, for many reasons, this last suggestion would be the most acceptable course of action. Supposing, then, that a government department was created, and that companies were formed in the manner and for the purpose before alluded to, the objects to be attained by the associations would be as follows:

1st. To acquire freehold lands.

2nd. To drain and irrigate land, and control rivers by embankments within the district where such lands are situated.

3rd. To supply power and superintendence for the purpose of cleaning cotton and for deep ploughing the land.

4th. To warehouse and convey along canals or otherwise the cotton or other produce from such land to the shipping places for the persons to whom such produce may belong.

5th. To let at annual rentals the lands so acquired for cultivation, subject to the conditions stated at 2, 3, and 4, and combined with especial conditions and stipulations as to the routine of cultivation.

6th. When barrages of rivers are constructed, to use or let the mechanical power derivable from overfall water at such barrages.

7th. To take tolls upon such rivers as are rendered navigable by the construction of barrages across them, as well as on such irrigating canals as are capable of being used for the purpose of intercommunication.

It will be seen by this system of arrangement that the administration of European improvements would be maintained in the hands of Europeans, and the detailed cultivation and gathering the crops would appertain to natives only. By this means it is thought that the best results would be attained which the land is capable of giving, and that the most perfect system of irrigation as well as tillage and planting would be ensured; at the same time, the countries so cultivated would have in every direction a complete intercommunication by canals and roads, which canals and roads would be created by the formation of the works required for effecting the irrigations. Of course the subordinate divisions would have to be formed so as to extend over either one or several contiguous collectorates of India, and to which the systems of irrigation would apply, or which collectorates require agricultural improvements to be effected on so large a scale that combined means only could be resorted to. Some of the capital would be subscribed in each division of country for the improvements demanded for that country alone, the rest being raised by the European capitalist; but in order that the system may work efficiently a general department must control, advise, and direct the subordinate divisions, the geographical extent and boundary of each district being regulated by the drainage areas of the great rivers; and this brings prominently forward the question as to the propriety and necessity of creating a public works department in India similar in its functions, but much more extensive, than the "Waterstaat" of Holland; and if we look at the fact that India is more dependent than any country on the correct adjustment of the flow, direction, and level of water (whether used for irrigation, intercommunication, or by embanking rivers, or by the abstracting of water from marshes or low-lying ground), the conclusion becomes irresistible, that until an efficient and active public department is created having the full concurrence and support of the government and country, the agricultural capability of India will never be either understood or developed; but, with a department of this description, the subordinate associations I have alluded to could then act with efficiency, and the well-grounded complaint would cease, "that in India the general results derived from each acre of tillage is less than the produce obtained from an equal area of any other cultivated land known."

CHAPTER III.

CONSIDERATIONS RELATIVE TO THE BARRAGE OF RIVERS, THE IMPOUNDING AND DISTRIBUTION OF WATER, AND THE SEVERAL METHODS BY WHICH IRRIGATION MAY BE ACCOMPLISHED.

THE preceding observations relative to irrigation have been so far limited to the countries specially referred to, but now it becomes necessary further to speak of those great engineering works which are indispensable for the full development of tropical cultivation, and which observations are both applicable, more or less, to all rivers having a variable water surface, as well as to the cultivation and growth of other vegetable products besides that of cotton.

All tropical rivers are periodically influenced either by an excess or want of water; the water area is frequently reduced so much that perhaps at one time the river may only occupy from a fortieth to a four-hundredth part of the area of its ordinary volume; whilst at another time it overflows and inundates all the country lying on each side of it. These circumstances occurring, the lands through which the rivers flow are either unduly saturated or too dry (tap-root plants alone sustaining themselves after the general vegetation has ceased to grow); hence the tropical cultivator is compelled to watch the seasons, and to adjust the seed-time, so that the woody fibre and stems of plants are formed before the dry season is too much advanced, or before the subterranean water level is sunk beyond the reach of capillary action.

This state of circumstances tells much on the agricultural prosperity of India, for in that country, unless aided by some irrigation, all cultivation in the dry season necessarily ceases.

In some countries, however, the effect of the dry season is guarded against, from the facility by which cuts and canals are made, and the needful supply of water obtained from the interior, as in Demerara, Berbice, Surinam, and in some parts of Georgia; but it may be said that there is a total absence in all tropical countries of that due provision for regulating the state of the water on which so much depends. This remark, however, will apply to India more strongly than to any other cultivated country.

In respect to tropical rainfall in most countries it is so large in quantity, and descends in so short a time, that persons resident in the temperate zones cannot in all respects realise the effect of either the absence of rain or its excess. It is sufficient to state that from sixty to one hundred inches of rain often fall within six months, and on tropical mountains much more: hence the vast size of the rivers within the tropics, and the great extent of the material forming the rich diluvial and alluvial plains, which the incessant flow of these rivers has brought from the high levels and distant mountains, and in whose recesses the innumerable sources of these streams are hid.

So changeable are the great tropical rivers when crossing level plains, that the current is both narrowed and shoaled in dry seasons, whereby navigation ceases and the rivers are almost lost. Again, during the rainy season, the whole of the channel space, both in width and depth, is full to overflow, and the waters then expand over the level plains, because there are neither banks or washes, as with us, to confine the flood in a more narrow space. After the period of saturation, the time arrives for agues, intermittents, and those diseases consequent on water being detained in stagnant pools and lower spaces, and so it often remains, until evaporation once more leaves the country an arid and dusty plain.

A peculiarity belonging to the great tropical river or rivers running through countries having dry seasons (and crossing deltas or alluvial plains), is the fact that the beds of these rivers are often as high, and the banks much higher, than other remote portions of the neighbouring country, so that the overflow diverges from the river at nearly right angles to the direct flow.

The cause of the bed and sides of these rivers rising above the natural level of the surrounding plains is due to the earthy matter held and maintained in suspension by the natural flow being deposited in proportion as velocity is diminished; consequently, the surface of the land is increased in height as the water spreads over the country, the earthy deposit being lodged in the largest quantity near the river which the flood waters have recently left.

It is requisite to form a just appreciation of the difficulty of dealing with and regulating the flow of tropical rivers, so as by their means to irrigate the countries through which they pass, and in order to do this it has been necessary thus far to describe their peculiar characteristics as compared with other rivers in the temperate regions, and from this slight description the fact may be gathered that to control the levels of the water-surface of these rivers engineering works of vast magnitude will be required, and so arranged mechanically that, whilst they will be capable of resisting and of maintaining at full height a portion of, or, if need be, the whole stream, in the dry season, or in a semi-dry season, at its full height, yet so flexible in control, that during heavy floods no impediment to the currents should remain to resist the natural course of such stream; and it is only after great reflection, much study, and the strictest personal investigation of the nature of many tropical rivers, added to a long experience in hydraulic works, that I dare pronounce the barrage of great tropical rivers to be practicable to an extent which will ensure their levels being maintained to a height which will in most cases permit of the water being conducted for irrigating purposes over the lands on either side, and in all cases of such water being distributed over the bordering land by means of a minimum mechanical lift, and at the least expense for elevation.

It will now be necessary to describe what is the meaning of the term barrage of rivers.

The earliest use of barring a river is to be found in the permanent dams placed across streams and water-courses, so as to retain or increase their depth, for the purpose of either rendering the river navigable, or obtaining a fall for the purpose of propelling machinery; the unused water in such cases being then conducted through sluices, or over by-washes, dams, tumbling bays, or overfalls, prepared to carry it off, and, in case of floods arising in the river, sluices were opened in the main work so as to prevent the flood overflowing and injuring the side dams. Such works are to be seen on the Thames, on some parts of the Seine, and on various canalised European rivers, but, as compared with tropical rivers, they are small; great floods seldom occur, because the rainfall in the temperate zones are very equal; they neither admit of an analogy being drawn from them, or furnish a work the principle of which could be applied to a tropical river. Nevertheless, in France, some excellent examples of movable barrages have been constructed, which at all events serve to exemplify the great value of impounding the volume of water of a river, during dry seasons, by means of dams which may be moved entirely away during heavy floods.

In India and in the island of Ceylon tanks and impounding reservoirs have been constructed, from the earliest times, for detaining, storing, and regulating the supply of water for irrigation, or the improvement of navigation, or for both these purposes, and some of these works in Ceylon are so vast, the material so stable, and the design so scientific, that they might easily be restored with great advantage to their ancient use, by which means vast tracks of country would become again fertile, and immense agricultural wealth would be derived from a soil which is now merely waste and jungle. These works are more of a character resembling immense reservoirs and tanks than barrages for arresting the current of a large river, and it is perhaps reserved for our own times to exhibit a work of the latter kind.

The names of Colonel Baird Smith and Colonel Cotton in India have been long associated with works of great magnitude and importance, the former having designed and constructed the annicut of the Godavery river, from which work great profits have resulted, by bringing into activity a system of irrigation which has been of the greatest benefit wherever the influence of these works has caused the water to flow.

The works alluded to, and which are called annicuts, are only partially-formed dams for keeping the water to a certain level only, and at high flood the dam is permanently left in the river, over which the flood flows. The disadvantage of this system of detaining the water of the river arises from the imperative necessity which exists of keeping down the work, so as to avoid too great an obstruction to the river when it is at full flood; on the other hand, by its low level, the area to be irrigated is more limited than would have been the case had the dams been higher; but again, had such been the case, the chance of inundating the upper country by the erection of higher dams would have been greatly increased.

To irrigate the land bordering on the Indian rivers, so as to grow great quantities of cotton, corn, flax, hemp, and other crops, to improve the navigation and turn the soil to the best and most profitable account, the annicut system will not meet the requirements for the accomplishment of these objects, and it is only by a system of perfect barrages that the permanent level of the water will be effectually maintained.

The greatest undertaking ever yet attempted to bar a large river is the great work designed, and to a certain extent accomplished, by Monsieur Linant, a celebrated French engineer in the service of his Highness the Viceroy of Egypt, and which work is intended to raise the levels of the two branches of the River Nile to an extent which shall admit of large districts being irrigated by natural flow, and other districts to be also watered by a diminished mechanical lift. It is certain, that had this work been accomplished to the full extent of the original design, and all the good derived from it which so great an undertaking ought to be capable of effecting, the annual revenue of Egypt might, at this period, have been quadrupled at least.

At present the piers and arches of a great bridge of communication across both branches of the Nile at their separation have been erected and completed. These piers are founded very deep, so as not to be injured by the scour of the river; they are also of a greater transversal width than that required by the roadway. To these piers it was intended to attach the gates for shutting the Nile, and raising the surface of its level to a point which should thereby be capable of irrigating a vast extent of country above the Delta by throwing the waters back to the upper levels; the irrigation below would then be effected by placing feeding-canals on a high level, the waters of which would flow through and supply part of the districts of Ghizeh and the Lower Delta.

The arches of this work are thirty feet span; the piers are each of a convenient width for the affixing and working the machinery for the requisite sluices, the gates of which were intended to be attached to the piers.

The whole of these works are designed and carried out in a manner to reflect the highest credit on the engineer entrusted with their conduct, and show a liberality in supplying funds by his Highness the late Mehemet Ali for so vast a work, that it creates astonishment at seeing so much is done, and yet that no effort is now made to finally complete this noble work. Had the efficiency of this great enterprise been brought to a successful issue the example would have had the most beneficial effect in stimulating the introduction of similar works in India and other countries. Be this as it may, it is certain that now, to complete this work, it will be necessary to diverge from the original design, to place a system of caissonage against this structure, which would be of a nature to admit of its entire removal during high Nile, and to restore it again to its original position when the Nile has become sufficiently low to render it advisable to again recommence the maintenance of its levels.

As the system of barrage here proposed is the same which I recommend for all tropical rivers, or rivers liable to a variable area of volume, I will now proceed to describe the system in detail, so as to show the construction and principle of application.

We must, in the first place, select for the site of the intended barrage a reach of the river where the line of the current and the banks on each side thereof are parallel, or where the river may be made parallel, and is rather broader than its usual width, so that the current will be slower in that part than that of the general current. Two parallel revetement walls are to be built on each side of the river banks; one portion of these walls will be above stream and the other below stream. From the line of piers these walls must be founded as deep as the piers. They are intended to preserve the depth of the river across, and to maintain an equality in every part of the current, so that no sand, mud, or shingle may accumulate at any time near the works. A system of piers must be sunk in and across the bed of the river to a considerable depth, and of a width calculated to withstand the pressure of the water when the down-stream is lowest and the up-stream is high. The spaces between the piers may perhaps range from thirty to forty feet on the clear, the number depending on the width of the river.

Between the piers, and for some distance above and below them, a solid floor of concrete, formed with hydraulic cement, is to be laid of at least three feet thick, the upper surface of which bed must be exactly level with the bed of the river. The object of forming this floor of concrete is to prepare a perfect seat for the caissons described hereafter to rest upon when the damming of the river is in action, and also to obtain a smooth surface on which the scour may act when the caissons are partially raised; for, without these precautions, the scour may become very irregular, and the stability of the work might be compromised.

All these preparatory works being completed, the operations for effecting the barrage may be commenced. This will be best accomplished by causing cellular caissons of wrought-iron to be constructed of adequate length and of a width to fill the spaces between the piers, but having wider ends or spreads to rest against half of the up-stream end of the pier, and which pier will form the abutment for the caissons. The cellular caissons, being brought to their destination, may have water let in, which causes them to sink gently to their place, and then will commence the rise of the surface level of the river.

When the river rises over the caissons they will form the tumbling bays required for the fall of the water, and must be built on the down-stream end of the caissons in graduated steps, so as to break the force of the cataract; the concrete bed at its lower end will then form the apron for the fall of water to act upon. Of course one narrow and hollow part of each caisson must in its construction be brought above the water, so as to establish at all times a connexion between the caisson (although buried under water) and the works above. The necessary height of the caisson must be judged of according to the usual vein or thickness of the stream, and the altitude to which it is judged necessary to raise the level of the river.

When the river, from falls of rain, from the melting of snows on distant mountains, or from a combination of these and other causes, has risen to a considerable height, so as to make it desirable that the artificial obstruction or system of caissonage should be wholly or partially removed, operations may be effected by pumping some of the contained water from the cells of the caissons; and at first, as the slight flotation which this operation will give them, the water will pass both over and below, but afterwards, when the river increases in volume, they may be so raised as to cause all the water to pass under, and ultimately the cells may be entirely freed from water; so that the caissons will freely float, thereby offering only so slight an obstruction that the velocity of the water will only be increased in a small degree; during heavy floods they may be moved away altogether, until the river has so far again sunk to a fitting level for the barrage to be again recommenced to meet the requirements of a new season.

The raising the caissons by the abstraction of their contents will be best performed by a fixed engine, and by a system of flexible and permanent hose communicating with all parts of the barrage, by which means the operations may be conducted with great despatch and regularity.

In such cases, as where the navigation is a question of serious consequence, a permanent side-lock, or a lock on each side of the river, must be provided, so that vessels may pass from the lower to the upper levels without interruption.

It will readily be seen that sluice-gates and all the usual appendages hitherto supposed to be indispensable to working and maintaining the levels of an ordinary river are not referred to in this description, and for the purposes of effecting the barrage of large rivers they may be considered inapplicable. It may be as well to state that the engineer who depends on such resources for effecting his great objects will be disappointed in his results, and will be in constant tribulation and dread lest the machinery may not act with sufficient rapidity, or be adequate to the occasion. Besides, the irregularity of the scour, and the impossibility of entirely removing with rapidity all obstacles when the river suddenly contains a large volume of water, will at once point out the necessity of employing more powerful and adequate means of annually meeting so serious a contingency.

Many variations in the system described may be made, but, if perfect, they will all result in the adoption and modification of cellular caisson, which can be either suddenly sunk or raised without human labour, and without the intervention of complex machinery, and which, during floods, may be completely removed, so as to leave the river entirely to an uninterrupted flow.

CHAPTER IV.

CONSIDERATIONS RELATIVE TO TROPICAL IRRIGATION.

THE barrage of a great river will, as a natural consequence of its adoption, exercise a most powerful influence on the agricultural productiveness of a country, and in an eminent degree contribute to its wealth, prosperity, and advancement, more especially in those territories where there are annual seasons of protracted drought, as in India, or where the country is nearly rainless, as in Egypt. There the proper admission of water to the soil constitutes the wealth, just as the abstraction of the superabundance from the soil contributes so largely to the agricultural prosperity of countries like Holland. In addition to the agricultural advancement which a system of barrage would create, the improvements of the navigation of rivers by the same means would alone constitute a strong reason for undertaking the work. To bar the upper waters of a large river will always require the resources, foresight, and judgment of a first-class engineer, and I would advise no one to engage in the work without first looking well at the probable result which will arise at each step of the undertaking, and the contingencies which may occur to retard or obstruct the work; but having decided the plan to be pursued, and possessing the experience and judgment which will enable him to carry it out, and feeling also confident that the employment of the means he intends to use will accomplish all the objects desired, then he may enter on the work with courage, energy, and discretion. He will find the river he is employed to deal with will be subdued to his will, and instead of being a running waste of water, it will afterwards duly administer a sustenance to the land, and give wealth (that is to say, the means of living) to millions of people, and return ample interest for the money expended on the undertaking.

At this point it will be well to pause for the purpose of explaining an agricultural principle, a perfect knowledge of which is of the most vital importance, and indispensable to the correct application of water to land as a means of irrigation.

If water rises to the surface of the land by capillary attraction only, or if water or air descend into the land conjointly, as they do during periodic rainfall, or intermittent surface irrigation, the soil, in such circumstances, remains only moistened after the superfluity has descended; the air will then occupy a considerable space in the land, in which condition plants useful and sustentatious to animal life will (with light and warmth) grow, and render in fruitfulness the product which is required. But if the water rises to the surface from below in quantity so as to shut out the air from the soil, or if by irrigation the water for a lengthened period stagnates to an extent which excludes the air from descending, then the nature of all vegetable products change; useful and nutritious plants (excepting rice) cease to grow, and canes, reeds, and other aquatics, according to climate, take their place; and it is from co-operative conditions like these that the justly hated barren, useless, and unhealthy fens, bogs, morasses, swamps, and springy grounds are either created, maintained, or made to usurp the faculties which belong to a fruitful soil.

The above described, two opposite conditions of the soil must be studied and well comprehended before irrigation is attempted; and when understood, it will become obvious to the engineer that a capability of draining all superfluous water from the soil is as essential, and must precede the action of bringing water to it.

The various applications of water as one of the media by which the active fertility of the soil is maintained may be stated as follows:

Sub-irrigation by side penetration through a porous soil. This is carried on by means of cuts surrounding and intersecting the fields, and maintaining the sub-water at a due level, by which the ground is saturated below a certain point, and the moisture supplied above by capillary attraction drawn from the saturated stratum, the level of which is maintained by some neighbouring river or stream, which generally adjusts the level of the water in the side cuts. This mode of sub-irrigation is practised largely in Holland, Lincolnshire, Cambridgeshire, and other flat districts, and is termed draining, because the cuts are also the drains for taking off the surplus water derivable from rain; but if the water was not maintained in these cuts in dry seasons, as well as the cuts kept free in the wet seasons, much injury would accrue. It is during the periods of dry weather that the cuts supply moisture by side penetration, and dissipates it by the capillary action required to operate through the vegetable soil, so as to feed the excess of evaporation in dry weather. It is the cheapest of all the means by which irrigation is effected, and gives such little trouble that many farmers and planters, from not seeing the subterranean operations going on, do not think that they are irrigating the soil at all, but are, nevertheless, well aware of the injurious effect arising from the water being too much lowered in the side cuts, whereby the upper surface of the land is too much dried. In Holland and the Low Countries, where the system is carried out to its full extent, the operations of the subterranean irrigation is well understood and profitably acted upon; the water-levels of the side cuts are accurately maintained (generally at two feet six inches below the land surface), and in winter the water-level often is raised slightly above the land surface, so as to shut off the effect of cold (ice being a bad conductor of heat), and thereby shielding the soil from the effect of the usual freezing atmosphere.

But the general system of what is termed and understood by irrigation is carried out by bed-work, and the spread of water is effected in the following manner: A canal conducts the water on a higher level than the beds, which are laid out in pairs with gentle slopes falling from each side of a smaller canal or duct placed along the upper head of each pair of beds. At the lower end of each bed a drain is also cut for taking off the surface water, which, after it has passed over the bedded surface and percolated through the soil to the foot-drain, the water is drawn off by the general discharging drains, which discharging drain may again form a canal for supplying water to another series of beds lying on a lower level. This arrangement is called in England the water-meadow system, but in Italy, and especially in Lombardy, it is the prevalent method of watering the ground—not alone for grass, but for the production of various crops in general—and has been very extensively used in that country from the earliest times. For the purpose of obtaining the best supply of water from a commanding level many fine canals have been constructed on highly scientific principles, and perhaps this division of engineering is better understood in Lombardy, in Holland, and in the Dutch colonies, than in any other part of the world; but in both these countries necessity compels the inhabitants to pay great respect to the means by which the flow of water is directed. In the first-named country the object is to obtain moisture in the exceedingly dry portions of the year; in the last-named country to get rid of that part of the rainfall which is in excess of either evaporation or produced by sudden rainfall. These two necessities have been the parent in both countries of excellent rules and laws for either obtaining by combined means a supply of agricultural water, or to drain lands of the excess of rainfall beyond that of evaporation, and to ensure to individuals in proportion to the extent of their holdings the full benefits of these useful and indispensable undertakings.

In Egypt, where rainfall is very unusual, an imperfect and uncertain, but very extensive course of irrigation is resorted to, and which may be termed swamp irrigation. This irrigation is divided into two parts: first, by promoting some portion of the growth of a plant before the moisture left by the inundation or the overflow of a river is evaporated from the soil; and, second, obtaining water by an artificial lift from wells from neighbouring rivers or tanks, and conducting the water through drains cut in the headlands of fields, and distributing it from thence over the surface of the ground, so as to swamp it with a considerable excess of water, which water will maintain vegetable growth ten or fourteen days, when the same process of irrigation has to be repeated. It is obvious, however, that if the ground is a porous sandy soil, much water will sink therein beyond the reach of capillary attraction; and so much may this be the case, that I have known two noble farms belonging to his Highness the Pacha of Egypt, where the water was pumped in one example to an average lift of eighteen feet, and the other eleven feet, by steam power at a very considerable expense, yet at least five-sixths of the water sank below the roots of the plants, and was, therefore, lost altogether; yet, in spite of these adverse circumstances, the farms in question pay well, so favourable is the climate and the soil, if water is always present to feed the plant with moisture.

In some circumstances, as in that of garden or small-field culture, the irrigation is often effected by pouring water to the root of the plant by hand, in which case no more water is given than is needful. This course of proceeding, though much practised in the East, is exceptional, and does not come within the category of a regular system of irrigation.

The soils to be irrigated vary so much as to texture, porosity, levels, facility for draining the surplusage water, and in regard to other circumstances, that it is impossible to lay down any fixed rule for effecting the object; but it may be stated that for the following class of soil the system now to be described may be, with certain modifications, adopted:

No. 1. Clay soils, or loams, which retain water, but which shrink on drying, and, consequently, crack into innumerable small fissures.

No. 2. Loam soil, slightly porous, which contain a sufficient quantity of siliceous particles to prevent cracking after the water is evaporated from the surface.

No. 3. Sandy soils, having sufficient aluminous matter mixed with the particles, so as to puddle the drains and prevent the water from being absorbed too soon, so as to sink past the root of the plant, and consequently be lost.

No. 4. Decided sandy soils, which will neither retain water in either a canal, a drain, or in the cultivated land.

No. 5. Reclaimed swamp soil, or prairie soil, o salt marsh soil, composed of vegetable earthy matter, combined and mixed with fine and minute particles of silex, and capable of maintaining a water-level four feet below the surface of the ground.

No. 6. Side-lying ground of various textures.

Under ordinary circumstances, and in our country, a soil as that of No. 1 would be pronounced unfit for irrigation; but as extensive rich tracts of such soils exist in tropical situations favourable for receiving a supply of water, of course it is needful that recourse be made to some means by which a supply of moisture may be obtained. A large portion of the Delta of Egypt is composed of stiff clay, which will harden like a burned brick, and, indeed, this clay is often made into sun-dried bricks (specimens of which are still seen in walls four or five thousand years old). This soil, though stubborn in the extreme when divested of moisture, and much like the stiffest London clay (of which it is a counterpart), produces, with the application of water, most excellent crops. But then the sun is always shining in Egypt; consequently, when the soil is free from water, it immediately cracks in all directions, and by that means receives water into its pores, in a manner which we could not calculate upon in Northern Europe. Of course great care is required on the part of the cultivator to see that the ground does not get too dry, otherwise the crop may be lost; but an application of water over the surface every ten or fourteen days is sufficient in the cold season, but oftener than this, according to circumstances, in the hot season. The most favourable soil for irrigation in a hot and dry climate is No. 2, which has a strong absorbent power, and capable of taking up moisture without letting through, and consequently losing by its porosity any considerable quantity of water.

No. 3 soil only varies from No. 2 in its excess of porosity. A soil of such texture, and having the requisite fertilising properties combined in it, will bear good crops of cotton, flax, hemp, sugar, and other useful products, but will absorb more water than that requisite to supply evaporation, by reason of its liability to lose water through soakage. But if the principal canals and drains are puddled, and proper precautions are taken, the irrigation may be carried on, in the manner to be hereafter described, so that not much water will be lost in the process.

No. 4 may be a good soil, and yet to irrigate it by the ordinary method of flooding is to incur a waste of water, which ought by all means to be avoided. But it is not alone the waste of water to be regarded as an evil, for should there be lower grounds in the vicinity, and of the same character and texture of soil, such lands will often be converted into useless saline swamps, caused by the superabundance of the water derivable from the irrigated ground. Even in Lombardy, where irrigation is so scientifically and systematically carried on, it is thought that for every acre of porous ground improved, an acre of similar ground on a lower level is injured by excess of side saturation.

No. 5.—If such a soil has a water-level about three feet below the surface, or if this water-level can be created, then swamping is unnecessary, because, with a sufficiency of fall for draining, side irrigation may be carried on, and the requisite moisture demanded for cultivation will rise by capillary attraction, and supply the loss caused by solar evaporation, as before described.

No. 6.—When ground to be irrigated is side-lying, that is to say, when the slope is considerable, then the only course which can be pursued is to contour it into levels or terraces, and to make cuts or feeding canals along the lines of the contour, giving only the requisite fall for carrying the water onward. This fall will not much exceed three inches per mile, and even then stop-gates or regulators will be requisite to throw back or detain the water, so as to cause it to overflow the downward side of the feeder banks, and which are levelled and sloped so as to allow the water to run over them in a sheet, and not by gullies. Of course the irrigation will divert the water over the ground in an equable quantity by small directing drains, taking their water from the subordinate canals; in most cases the ultimate distributing drains will be thrown up in a temporary manner, the water required for saturation will spread over, and to a certain depth sink into the ground, and, if possible, the superfluity should be collected in the next feeding or catchwater canal, and so on, until the whole area is completely moistened.

If the soil is very porous, then, undoubtedly, some water will be lost by sinkage, for which there is no help, except that of running a road along the principal lines of contours, close to and parallel with the feeding canals, on which a movable engine will travel slowly and will irrigate by spray—pumping through hose pipes—causing artificial rain, instead of swamping the ground by overflow from the canals, as described before. The advantage of this last course of proceeding is this: once in every seven days a shower may be delivered over the crop equal to two inches of rainfall, which will have the effect of washing the growing plant in an effective manner. This last circumstance is of great consequence, especially in a hot, dry climate, when the ground and the plants are often very dusty; of course, in any case, it will be needful to puddle the contour canals.

We have thus far numerically described the soils which are most likely to be brought under irrigative culture, and, with the exception of No. 6, may now be dismissed. We will therefore proceed to describe that system of tropical or semi-tropical culture by irrigation which may be carried on with advantage and profit, premising, however, that irrigating by bed-work, as practised in Lombardy and on our water-meadow systems, is inapplicable on the large scale in or near the tropics, and too expensive to be introduced, inasmuch as laying out the beds, cutting and maintaining drains and carriers, would cost more than the amount for effecting the whole system of irrigation now proposed, including the supply of water, and putting in and subsequently gathering the first crop.

In commencing a great system of irrigation, we must suppose that an adequate supply of water is secured by retaining, throughout the dry seasons, the level of a river by barrage, or that the river will be diverted from its natural course at an upper and distant level into a feeding canal; or otherwise that mechanical power will be employed to give the necessary lift for transferring the water from the lower levels of the rivers where no barrage exists; or that the water is derivable from wells, tanks, or lakes; and further, that several of these sources of supply will be made use of in a greater or less degree of combination.

The next question to settle is the direction and elevation of the great feeding canals: these should, as far as circumstances will admit of, take a course at right angles to the river, and should be of an elevation to command all the ground to be irrigated. This question of command is of such great consequence to the favourable working of the system, that if the river be liable to fall too low to adequately maintain the supply at a proper level in the superior feeding canals, it will be better to adopt the use of mechanical power as an auxiliary agent for maintaining the command in the levels of the great canals, as an addition to the altitude obtained by that of barrage.

From the superior or great canals there should branch off subordinate or divisional canals of distribution, but which canals must also fully maintain their command above the lands to be supplied with water. These subordinate canals will generally form the boundary of separate properties; and, in the case of an extensive system of cultivation being adopted, they may be constructed of sufficient size to be used as local navigations for facilitating the removal of the produce.

The canals for feeding and distributing the water, it will be seen, are described as being placed entirely above the level of the ground to be irrigated; we will now also describe a system of cuts which should be placed below such level. The upper surface of the water in these cuts should be, under ordinary circumstances, not nearer the surface level of the ground than two feet six inches; they will serve a threefold purpose by supplying moisture by side irrigation, and they supply water for swamp irrigation, that is to say, for laying the ground under water for a few hours, at intervals of time varying from seven to fourteen days; and they also serve the purpose of drains for drawing off the superfluous water during havy rains, or after the ground has been subjected to swamp irrigation.

The laying out these cuts and properly circulating the water through them will always be a work requiring considerable skill, the width, depth, and distance from each other depending on the extent of the system embraced within the influence of the great feeders, and the nature and texture of the ground to be irrigated.

In addition to the care and discretion required to be exercised in laying out these canals, conduits, cuts, and drains, the levels of each division or section of the general system, that is to say, a certain area, which will have its high-level feeding canal and its low-level exhausting cut or drain, laid so that, by a gradual fall, a circulation of water through all parts of the area will be effected; and this circulation is required to be continuous in dry seasons during the growth of the crop (except at such periods as will be considered proper for swamping the ground), but immediately after which the exhaust drains must be put into full activity again to free the ground of surplus water, so as not to interrupt the growth of the crop, or encourage (as in the case of cotton crop) a too exuberant production of wood. This brings us to an important consideration, namely, the proper course of proceedings to be adopted in reference to laying out and forming the exhaust drains.

It has before been stated that irrigation should at all times be preceded by drainage. This expression does not apply to, or mean, the putting in the ground drain-tiles, or constructing covered drains as is practised in climates colder than those we have been speaking of, but the draining alluded to is carrying off the surplus water after the ground has been saturated by swamp irrigation or otherwise by rain, but which is generally (in tropical irrigation) left for the sun to remove, and, in many cases, vast tracts lying on lower levels are injured by the superabundance of the water flowing from the upper irrigated lands. The detriment produced by this system has been dwelt upon before, and it cannot be too often repeated, that, after the ground has been moistened, the water cannot be lowered too soon so as to allow the action of the air circulating within the earth to co-operate with the root of the plant in promoting to the fullest extent the vegetable increase above.

Bearing in mind these important considerations, we must see how far the proper application of exhausting drains serve, not only to remove the imperfections of the present system of irrigation as practised in India, but will also tend to increase, in an eminent degree, to the general productiveness of the soil, and in conjunction with the high-level feeders obtain that command of water circulation which will ensure the highest amount of productiveness a given area of land can give, and that with least expense of labour in tillage.

In order to explain the subject as clear as written explanations are capable of making it, we must suppose that an irrigating section (being part of a general system) consists of an area of two thousand acres, and either the principal or a subordinate high-level feeder runs along one side of this area, and at one point will join other sections of a similar area, also at the immediate junction of the high-level feeder. Now, as all the exhausting drains converge to this junction, where an engine power and scoop-wheel or centrifugal pump will be located, there will be the means through the action of the exhaust drains of lifting the swamping water from one area to another, because the lowest part of the exhausting drain of one will be in proximity to the three neighbouring areas, at the highest end of the feeding canals belonging to each division respectively, on which account, and by the action of proper sluice-gates and breasts, the water may, for the purpose of swamping,* be transferred to a part or the whole of another area, or returned to the canals; a reversed action may also be made, and the water returned back again to any of the other areas from which it may have been previously withdrawn. By these means water may be kept in a state of circulation through all the exhaust drains, and so be spread over the surface of the land to an extent of eight thousand acres, by the employment only of one scoop-wheel, or centrifugal-pump, and one steam-engine, using a lift of not more than seven feet, and at the same time avoiding any deterioration of land by the stagnation of water.

Of course an irrigated district would be composed of quadrupled areas, arranged as those above described, but varying in extent, according to local circumstances.

As evaporation will waste the water in a very rapid manner it will be requisite that a supply adequate to this waste be let in from the feeding canals. This evaporation will cool the ground in a very quick and beneficial manner. A plan of the junction of the four areas, and the arrangement for overcoming the lift and working the sluice-gate, is appended to this report.

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* This system of swamp irrigation must not be mistaken for the swamp irrigation of India or Egypt, which in neither case is a circulation of the water employed.

The lands, which may be irrigated by the method just described, are such as have been classed as No. 1, 2, and 3; but much discretion must still be used in reference to the quantity of water to be applied, to the necessity of occasionally swamping the ground, to moisten, and also to cool it, the duration of such swamping, and other matters connected with the operations, all of which will in some degree be diversified, according to the variations of soil, climate, and experience.

No. 4 soil (see *anti*) will generally be found along the alluvial plains bordering the sea-shore, or parallel to some great river near its mouth; such a soil is well adapted for growing cotton and other produce, provided it contains calcarious matter, together with some alumina, silica, salts, and organic particles, and is not in its composition a decided quartziferous sand. A soil like No. 4 is cheap to work, but difficult to irrigate if its dry season sub-water level is below four feet from the surface of the ground. The difficulty of irrigating such a soil arises from the rapid power it possesses of absorbing the water put upon it, and also the necessity which arises of always lining the canals, drains, and works, with clay-puddle, so as to retain the water therein. On such lands it is requisite to pursue a different course of proceeding, which we will describe as concisely as possible.

Suppose through a district principally composed of such land as we have just described a principal conducting or feeding-canal is carried, and this canal, together with the collateral distributing canals, are lined with impervious clay or puddle, in the same manner as our navigable canals are in this country, and also what we have before called exhausting-drains, have likewise been lined in the same manner, from this point, then the water may be prevented from sinking; but it is obvious the system can be carried no further. It is therefore requisite to set the drains at such a distance from each other as to make them available, as small navigable canals, to carry a square light draft vessel of iron, containing a steam-pumping engine, by which, and by the use of hose, the water may be spread over the intervening space between the two canals, the vessel being moved on only in proportion as the work proceeds. The advantage of the system is this, the intervening space of ground between the canals may be ploughed and otherwise cultivated by means of the same engines as are used for pumping, likewise the cleaning and packing-machines, required in cotton culture, may be actuated in a similar manner, not, of course at the same time, but at such periods as the irrigation is not going on, it being obvious that irrigation is not required during the time of ploughing, nor at the period of cleaning cotton or flax, or preparing for the cultivation of any crops.

It undoubtedly is a most important question to consider what are the proper distances between the exhaust drains or canals situated on lands which will maintain the water-level, and on which canals the boats or vessels are to be placed for carrying engines which will perform the operation of ploughing. I am inclined to believe that the Dutch plantation system, as seen on the coast of Guiana, Berbice, Surinam, and Demerara, afforded the best examples of hydraulic arrangement in this respect. The canals, placed on each side of the several plantations, are laid out and cut with the greatest care and exactitude, both as regards levels, slopes, and depth. These canals serve the purpose of draining the surplus water during the rain season, and for bringing water from the back country for side irrigation during the dry season, the level of the water in the canals being regulated by excellent sluices. The distance from chief canal to chief canal is, in Guiana, about two hundred and fifty yards, and five feet deep from the surface of the ground. This measurement of the canals is across the plantation, and these canals serve to bring the produce to the logies and mills. The canals are further connected with each other by cross drains of smaller dimensions, which divides the land into compartments. All the greater canals have banks on a higher level than the land, and which banks serve as road communications. And in addition to the canals described there are still further intersecting drains or cuts of a minor character, which also either bring water when required, or in the rain season take away the superfluity of the rainfall. These last described intersecting drains, which divide the land into beds of twelve feet wide, are numerous and shallow, not more than two feet six inches deep, and have but little slope given to the banks. It is thus seen that the ground is at all times well supplied with water, which will furnish abundant moisture to the land by side percolation, or, further, the same canals drain the land effectually at the proper season. It will also be seen that the canals on the side verge of the plantation would conveniently serve for the introduction of the steam plough, conjoined in its action with the floating caisson or vessels referred to before. It is true we are now discussing the best means of cultivating porous soil, whilst the soils just now alluded to in Guiana are generally retentive and unctuous soils; nevertheless it is thought advisable to show how valuable the outer canals are to well-conducted plantations, and that the spaces between these canals are about the most judicious which could be chosen, both in reference to the conduction of water and also for carrying out the best means of *applying steam power for cultivating purposes.* Of course, where the ground is porous the canals would require to be puddled, no cross drains would be wanted, therefore spray irrigation would in that case be the best to resort to.

In tropical countries there are no mosses or bog soils, because a moss-plant grows continuously from the top of its little green stem, gradually, and at the same time decaying from the lower end thereof, so that it is always converting the elements which it absorbs during its growth into a carbonaceous soil; it is charged through all its tissues with water, which it is continually exposing, through the instrumentality of its leaves, to the evaporative power of the atmosphere, conjoined to the action of solar warmth and light. The temperature of the moss-plant always or nearly approaches to an atmospheric mean; therefore the surface of bogs are more warm in winter than ordinary cultivated ground; and in summer, as may be perceived, they are cold and damp, but never pestiferous like a stagnant swamp. It must be clear, therefore, that moss can only flourish in countries where the atmosphere is equable and showers are frequent; for should a dry season occur, like those of the tropics, the moss-plant, although possessing so wonderful a vitality would be withered, and its capillary power of pumping water to supply evaporation would never again recover the action so necessary to perform the functions which nature has assigned it of making a soil where none existed before, and of covering rock and naked land with green vegetation; but, as nature is always manufacturing soil, and increasing the fertility of the earth by the decomposition of such plants as have been produced chiefly by water, light, and atmospheric influences, other equivalents to that of the northern bogs are produced in tropical and warm countries; these aquatics are reeds, jungle, grasses, canes, and often low jungle wood, and timber; the decay of all these, together with the admixture of the results of periodic inundation, charged with aluminous and silicious mud, forms a soil, which, when drained and irrigated, may be cultivated at less expense, and is not surpassed in productiveness by any known soil. This is the soil classed as No. 6; and as, in laying it out, the preparatory works required for its cultivation demand that canals should be formed, the procedure will be the same as applied to soil No. 4, with these exceptions, that as the subterranean waters are, or may be, maintained at a level of not less than three feet six inches from the surface, and as the soil has great capillary power, the canals are only required for the purposes of drainage and water supply, but may be made of a capacity sufficient for local navigation, also for carrying the machinery required for cleaning cotton, and the operation connected with steam cultivation. This last-described soil is analogous to the prairie soil of the American coast and river borders, and the savannah and pegass soil of the British, Spanish, French, and Dutch colonies.

In India it is the soil of the coast, and is often covered with swamp-salt, mud, and jungle. This latter soil—that is to say, soil formed by the decomposition of vegetable matter, aquatic animacules, and alluvial deposits—it will be seen that in its progress of formation, and during the decay of the vegetable products with which its surface is covered, is in an opposite condition to that of a bog covered with moss, for only in the latter case no putrid exhalation escapes from the swampy surface of the northern bog, which is of itself, and without admixture of other soils, incapable of productive cultivation, whilst the spontaneous products of the tropical swamp, and the annual decay of vegetable matter, cause the exhalations to be pestiferous, but the resultant soluble and insoluble matter enriches the earth, and, when drained, forms soils of inexhaustible fertility, and, by keeping the water at a proper level, and in constant and slow circulation, the healthful condition of the air may be preserved. It has been requisite to constitute this comparison between two swampy soils, in order to show that their conditions are entirely dissimilar, through the effect of climate and the difference of solar heat constantly acting on each.

CHAPTER V.

ON FORMING EMBANKMENTS FOR PROTECTING LAND FROM THE PERIODIC INUNDATION OF TROPICAL RIVERS.

MOST of the lands lying on the borders of tropical rivers are liable to be inundated, to a greater or less extent, during or after heavy rainfalls, or the melting of snow in very high and remote mountainous countries. It is on account of these inundations that the slope of alluvial lands through which the rivers flow falls laterally from the stream, because near the river the flood-water, after being spread over the surface of the ground, loses, by diminished velocity, the greatest portion of the earthy combination with which it is charged.

The bed of these rivers being often situated on the higher parts of deltas and alluvial plains great facilities for irrigation consequently exist; but as it is essential that the river be embanked on its sides, so as to restrain its spread within a limited space, and as it may be sometimes advantageous to distribute some of the retained water over the land, agriculturally, after the rains have ceased (that is to say, in a thin sheet, and only in quantity sufficient to leave a film of warp, or mud, the thickness of cartridge-paper, after which the water should be shut off), and then the agricultural proceedings should be pursued with all despatch.*

In England the waters of several rivers have been restrained, by important works, from flooding the low country through which they flow. These works are called the Washes. They are chiefly situated in Cambridgeshire, and have, and still continue to perform, those functions originally assigned to them.

It was justly thought that limiting the spread of water by the construction of solid earth embankments, a water-level higher than the surrounding country would be obtained, which would be accompanied with a greater fall towards the sea, and the increased depth, and consequently diminished friction of which would insure an increased velocity in the whole volume of water. These washes are generally about ten times wider than the river, and contain within the banks fertile meadows of great value, although subject to floods, and are, of course, never inhabited.

The advantage derivable from forming washes by means of straight banks is further increased by the action of the rivers being directed in a better line than before, so that the inclination existing in all rivers to assume a curvilinear direction in their course is much lessened by the direction which the current derives, during flood, from the straight lines of the embankment.

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* This operation, though simple, cannot be considered complete without a system of draining is also adopted.

Although sudden floods sometimes destroy the crops within the banks of these washes, yet, from the great fertility of the land (so often and so deeply inundated), the general value of the land is very high, and the profit derivable therefrom is equal to the protected land lying beyond the banks.

It is by means of high banks set back in a proportion relatively to the width of the river at the period of the largest volume of water existing during great floods that I recommend that rivers in India and other tropical and hot climates, when liable to inundation, should be governed and restrained from inundating the country.

The formation of a solid bank, with an inner slope composed of materials fit to resist the action of the currents during the time of flood, is very great, especially in a country destitute of stone. This difficulty is increased when the land consists of loam, soluble clay, or alluvial mud: hence the neglect within the tropics in erecting these great but useful barriers to resist the inundations which annually occur, although each mile of embankment would perhaps defend twenty miles of country, and not cost more than five shillings for each acre benefited, yet for want of knowledge, capital, and co-operation in the people, little is done to confine the rivers to a space parallel to and near their channels, or for utilising their waters during seasons of drought.

As it must be quite obvious that the adoption of nearly all systems of culture on an extensive scale must be accompanied with the needful regulation respecting the depth and width of those rivers from whence the water required for the purpose of irrigation is intended to be drawn, it is needful to make some remarks on the best mode of constructing the important embankments.

In England and the low countries, when a straight embankment is well grassed over the face is generally considered safe from the effects of floods, or the erosions caused by very heavy rain.

In the tropics, on the contrary, during very dry and hot weather the vegetation on a bank withers, leaving the faces and top dry and dusty, and when the heavy rains fall and the floods rise, the effect is to diminish the solid contents of the bank on all sides, and it soon becomes limited in its usefulness, or ceases to exist altogether.

But if the earth for forming the bank be properly thrown up from a cut on the landward side (which cut will afterwards form an exhausting drain), the slopes should be made by carrying on two prismatic lines of earth, having within each a circular toped flue two feet in diameter along the whole length of a division. This flue may be made of clay or loam, vitrified and dressed into shape. These triangular prisms will each be as high as the intended embankment, and the outer angle of the base of each will be the extreme width of it. After these prisms of clay have been vitrified (in the manner described hereafter), the space between them may be then filled with clay, having, if necessary, a small puddle-dyke carried up the centre and grafted for some depth in the ground on which the embankment stands.

To vitrify the clay in the prisms two openings are to be made at convenient distances in them. One of these openings will require to have a temporary fire hearth constructed and connected with the flue before spoken of; the other opening will require to have a small tubular steam-boiler placed over it, the steam from which will work a jet in a temporary iron chimney-stalk. This jet of steam will promote a quick draught through the flue, which draught may be urged at will to an extent sufficient to vitrify the prisms of clay in their place as deposited from the cuttings, and thus forming two faces to the bank of great and unyielding solidity, which will, if of sufficient dimensions, effectually shield the work from any injury whatever arising from the action of the flood, or erosion by tropical rainfall.

An embankment so constructed, but of an extra width, will, when so required, also serve to form a great road, and will consume more vitrified clay than that demanded for the slopes of a simple embankment. This extra quantity will be used in forming the footways, metalling the roads, and for such other use as may be incidental to a great thoroughfare.*

In all parts of the various countries referred to in this report roads are much required (even in the vicinity of, and leading to, the Indian railways), and all improvements in cultivation must be accompanied by road-making to an extent which will effect communication with and intersect the plantations and farms; but, as in the case of embankments, as before referred to, material is often wanting for their construction. The earth burned in the same manner as recommended for embankments (always taking the precaution to vitrify it) will in all respects answer the purpose when broken, and be so cheap in its application, that roads may be made in districts where it now is thought to be impossible on account of their cost to introduce them.

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* It may be observed that this system of vitrifying by the action of a steam jet, instead of burning the clay in heaps, as now practised, will produce blocks of hard and cheap material, will dress under the hammer like the best stone, but not so smooth, and will most materially serve all the useful purposes for which stone is required in engineering works. I believe I was the first who introduced burned clay for roads, railways, and other engineering uses; but at first there was more obloquy than admiration for this innovation, although it is now so extensively used. I trust, however, the method here described, together with the application of this material for embanking purposes, will meet with more cheerful adoption in the countries I have been referring to.

The fire-flues spoken of before may be made from the vitrified clay, after the first length is completely burned. See transverse section of embankment, and other details appended to the report.

CHAPTER VI.

ON THE SALT LANDS OF INDIA, AND OBSERVATIONS RELATIVE TO MANUFACTURING SALT, AND THE COLLECTION OF DUTY DERIVABLE THEREFROM.

In reading the preceding report on the growth of cotton and other crops it will be perceived that the observations relating to improvements have a more direct applicability to India than to any other country, and it will also be seen that considerable stress has been laid on the value of level and low-lying sea-shore lands for the purpose of cultivating cotton; but as the sea-shore lands of India are often occupied for the purpose of producing salt, some observation on the process of salt-making as practised in India is rendered necessary, principally to show how much more profitable it would be to the government to make the salt in a concentrated space, at convenient stations favourable for distribution, rather than in a wide-spread district, where it is difficult and almost impossible to superintend the manufacture, or collect all the revenue to which the government is entitled. In some districts of India the salt is made in salt-pans—that is to say, on sea-shore lands—a little below a good tide, but embanked sufficiently to prevent the retrocession of the water at the ebb. In other districts the air for a considerable portion of the year is very dry, and, when combined with solar heat, has sufficient power to crystallise the salt direct. From these pans the salt is raked, a good deal discoloured by the muddy earthen floor on which it is made.

In other parts of India the air has too much moisture combined with it to effect completely the crystallisation, as in Bengal. Here the action of solar heat only forms brine, and requires to have superadded the boiling process, which is still carried on in earthen vessels.

The lands embanked for the purpose are called salt lands, and the factories or sheds are distributed along the coast where the situation is most favourable to make and distribute the salt.

These manufactories, much dispersed, are extremely small, difficult to guard, and all the operations carried on in them are rude, costly, and primitive to a degree scarcely to be believed, especially when it is considered that a great and indispensable division of the state revenue of India is derived from this rude and ill-conducted manufacture.

No person employed to make salt has the means or can of himself commence the manufacture, unless the government, through their agents, make the necessary advance to carry it on; so that the salt and the works in which it is made are paid for even in the preliminary stage of preparing the muddy ground to receive the weak salt-water of some neighbouring creek, and, when produced, is grey and acrid from the foreign matters with which it is associated

Salt is also made in the interior, to a limited extent, from saline soil, but still in so rude a manner, and costly (if an excess of manual labour is considered as representing the price), that we wonder—and this observation applies to all parts and divisions of the salt question—how a process so destitute of all improvement and scientific progress can still hold its ground, and be conducted and sustained by an enlightened government. But our surprise is still further increased when we find that, instead of reducing as far as possible the great cost of the production of an article so indispensable to Hindoo life, on the sea-coast it is often the practice to tread the spontaneous and natural-formed salt into the ground by cattle, fearing the loss of revenue by smuggling should the salt remain within reach of the inhabitants.

Imported English white salt costs at Calcutta 2*l.* 12s. per ton, therefore we may presume that it costs the government that amount at least for the inferior grey salt produced along the whole coast of Bengal. In the two other presidencies salt is much cheaper, perhaps averaging to the governments from 6s. to 12s. per ton; but even a portion of this cost is caused by the insignificant dimension of the works individually, their great dispersion over the country, and the difficulty of effectually guarding them from great loss, caused by extensive smuggling.

To supply salt to India is a question, undoubtedly, as relates not only to the people, but also to the government, of vast moment; first, because of its great cost, especially in districts remote from the seaboard, and which cost is caused by reason of the great charges for transport, is further enhanced from the rude and uncultivated process of its manufacture, and the total absence of all mechanical appliances for abridging human labour employed in its production.

The question is also of great moment, if we properly appreciate the fact that there are one hundred and fifty millions of people requiring salt, at a rate of at least twelve pounds per head of population; and is still further of importance, if it is considered that the government depend for a considerable division of the revenue being always derivable from duty arising from the consumption of this article.

Notwithstanding all the great and complicated views the question admits of it is certain that from the north-east of Ceylon to the mouth of the Hooghly River, and in many other divisions of India, there are many localities where salt stations and manufactories could be placed, and where the inland communication could be perfected, the requisite shipping ports provided, and from whence steam transports could convey a considerable portion of the product to other maritime parts, and to situations within reach of navigable inland rivers at low freights, if facility were created for loading and discharging the cargo at these stations; these changes could be effected without occupying much land or employing many people. Great salt factories could be erected to make salt as clean and fine as that of Cheshire, on so limited an area that smuggling would be impossible; the cost of production would be so low that at least fifty per cent. on the expense of manufacture would be saved, besides leaving all the salt lands free for improvement and cultivation.

The saving derivable from the introduction of a superior system of salt manufacture would be least in Bombay and Madras, and greatest in Bengal.

It is not possible, within the limits of this paper, to describe the various works for perfecting the manufacture of salt by solar heat, or the processes by which the required results would be attained; but it may be stated that experience has been applied, the conclusions ascertained, and, without doubt, all the good which has been expected from replacing a bad by a perfect system may be fully realised, by the production of clean good salt, and, in addition to which, the land would be left free for cultivation.

CHAPTER VII.

OBSERVATIONS ON THE IRRIGATION OF DETACHED FARMS AND PLANTATIONS, SITUATED ON ALLUVIAL PLAINS, BY PIPEAGE, OR FEEDING AND DISTRIBUTING LAUNDERS.

As it will be frequently desirable and profitable to cultivate and irrigate detached areas of land far removed from river supply, and of so porous a character of soil that the distribution of water may become difficult on account of the absorbing nature of the earth, in such cases, however, this disadvantage may be overcome by obtaining from other countries some of the requisite mechanical appliances required to be used in aid of such means as the locality itself may afford.

Let it be supposed that the area to be cultivated is a parallelogram, and is limited to three hundred acres. A large well should be sunk in the centre of the land to the depth of the water-bearing strata, the earth taken from the well, and such other earth as may be required should be then thrown up to form a circular mound of at least forty feet in height, the earth to be disposed in such a manner that it will form a reservoir, the bottom of which will be ten feet above the level of the highest part of the area to be irrigated. The inner slope of the reservoir should be one to one, the top level of the bank should be ten feet wide, and the outer slope should be two or two and a half to one. The earth, as it is put into place, should be well beaten, and very slightly moistened to make it consolidate. The inside of the reservoir should be lined on the side and bottom with concrete, the mortar being formed from burned clay and hydraulic lime ground under edge-runners, and, when applied in hot weather, it should be kept covered with wet straw from sunshine until the lime is completely set.

The inside dimensions of the reservoir will require to be about one hundred and fifty feet at the top slope, and twenty feet deep, and will contain about five thousand tons of water, or one day's supply. This store of water will allow the engines being kept at work the twenty-four hours, whilst the distribution of water is limited to twelve hours.

From the reservoirs before described a straight fixed main launder should be placed, falling one-thirty-secondth part of an inch per yard, and extending across the property from side to side. This launder should have sluices across it at intervals of every four hundred yards, and outlets at the same distances to be occasionally opened, so as to admit water into the second series of launders, which will now be described.

The mode of distribution will be effected by using either pipes or portable-service launders, in which latter case the sides can be made to shut up by means of an india-rubber joint, and then be moved from place to place like simple boards.

These launders can be transported along the roads of the plantations by means of a carriage constructed for that purpose; when in use, they must be placed on portable trestles, graduated according to the exact fall required.

At intervals of two hundred yards either branch distribution hose, or lesser launders, can be used, having holes along the whole length, or other means can be resorted to, if so arranged and graduated that the outlets will cause the water to be spilled over all parts of the ground in equal quantities. The fall in the service-launders may be one-sixteenth of an inch per yard in length.

As the large portable-service launders should be placed along the lines of the narrow roads, which should be made to intersect the farm or plantation at every four hundred yards in width, there will arise only an occasional necessity to remove them, but as the distributory portion will require constant removal, the rows of trees (in the case of cotton culture) ought to be at right angles to the road, so that the distributing launders may pass between and slide over on the trestles.

The wind-engines used for raising the irrigation water will in seasons of rainfall be available for driving agricultural machines, such as cotton-jins, skutching-mills, and for meeting other demands of a like kind. The buildings containing the machines should therefore be placed near the wind-engines, so that the machinery and pumps can be connected or disconnected with facility to the wind-engine, which will be described hereafter.

The cost of commencing this description of cultivation will require an outlay of 8*l.* 10s. per acre. For the complete arrangement of a plantation, including first breaking up of the ground, the expense of the subsequent operations for obtaining a cotton crop will be:

	£	s.	d.
Annual interest on capital, 15 per cent. . . .	1	5	6
Cultivation, seeding, pruning, picking, distribution of the irrigation water, renewals, and packing the crop	2	12	0
	3	17	6
Produce from 400 to 700lb. per acre of clean long-stapled cotton, at 4d. per pound at the plantation	6	13	0
Leaving a profit of per acre	2	15	6

CHAPTER VIII.

OBSERVATIONS RELATIVE TO THE IMPROVEMENTS IN INDIA OF JHEELS OR MARSHES AND ISOLATED LANDS TOO REMOTE FROM RIVERS TO BE IRRIGATED THEREFROM.

ON the alluvial plains of India, especially those bordering upon the great rivers, there are depressions in the soil in which water collects during rainfall and inundation. These depressions of the surface are usually due to changes made in the course of rivers during flood by the usurpation of new and the abandonment of the ancient course of the streams; these depressions are numerous, and sometimes deep, often conspicuous by leaving the shape of the ancient river, and then performing the functions of a reservoir of vast dimensions: they are then called tanks. Others are often so filled with soil and silt that they are approachable for tillage on only the outer verge; they are then called jheels, the soil of which is rich and often moist, sometimes wet, and, near the centre, swamped with stagnant water retained by an impervious muddy bottom.

It must be clear that, however advantageous it may be to cultivate a portion of these depressions, no certainty exists that the plants will not be injured, either by inundation, or that the subterranean water left in the lowest part of the jheel will be exhausted by excess of evaporation before the growth of the crop is complete.

To remedy these difficulties, and to convert the whole surface of the jheel into useful land, it will be proper to sink a cylindrical shaft or sump in the centre or lowest part of the depression. This shaft should be of large diameter, and built of masonry, without mortar or cement at the joints; this will allow the water from the soil of the jheel to percolate through the walls without bringing in sand along with it. The depth of this shaft will not exceed perhaps ten or fifteen feet before an abundant supply of water will be found.

Round the outer edge or border of the jheel, a bank should be raised to cut off any inundation caused by the floods; the bank raised will also serve to form one of the banks of a high-level irrigating canal, the water from which may be distributed over the ground, by means of several series of minor canals, until it again reaches the shaft, or sump, before spoken of, into which the superfluous water not absorbed by irrigation will be again received.

Should the water derived from the drainage of the jheel, and raised from the shaft, be too large in quantity for irrigating purposes, an outlet for it must be sought for by extending the feeding canal, which conveys the water from the shaft, or sump, to the outer high-level irrigating canal, in which case the canal conveying the water to the outer high-level feeding canal and the extension beyond, will require to be kept sufficiently high to command and irrigate any convenient ground lying beyond the boundary of the high-level irrigating canal first spoken of.

The centre, or lowest part of every jheel, is, even in very dry weather, generally too wet for cultivation, and being often in the state of permanent swamp, is the reason for recommending the sump, or shaft, to be placed in the lowest point of the area to be cultivated, in order that the drainage may flow towards the shaft; should, however, the quantity of water required for irrigation be more than the drained sump can supply, or should the ground be porous, other wells at some distance, and situated on the line of the canal leading to the outer verge, must be sunk, for the purpose of obtaining an auxiliary supply to increase the volume of the inner or central sump supply; for it must be kept in mind that the extraneous inflow from distant sources, and inundations, has already been recommended to be cut off by an outer embankment, so that no water will be obtained except that derivable from direct downfall of rain and side percolation, but which quantities will generally be found sufficient for rendering the land cultivable.

When the ground is well cultivated the rainfall will on most occasions sink therein to a depth which will be represented by the line of the subterraneous water-level, the porous ground above which will gradually receive it. The meaning of the term subterranean water-level, because of its important bearing on this and other questions, will be explained hereafter.

Swamp lands, or jheels, when recovered, will become healthy, and will be found the richest and the most productive, and, on account of its gentle sloping character, the easiest and the least costly to cultivate of any we have had to deal with, notwithstanding, in their native uncultivated state, their vicinity is at certain seasons the most repugnant and unhealthy locality on which unhappy human beings can be placed.

Many jheels have natural outlets, but which outlets are too high and too much obstructed, from local causes, to allow the water to flow spontaneously therefrom; at all events to a sufficient depth to drain the bottom; for, as has often been stated before, it is not alone draining the surface which is sufficient to satisfy the wants of cultivation, it is indispensable that the master drain be placed at least four feet deep from the top surface of the ground, at its lowest part, and pass by the deepest point of the area to be drained. Such being the case, it will be needful that at this point a cut be brought up from the lower level of the outfall, through all obstruction; for, however accurately the water may be apportioned and laid on the ground, there must always be an excess beyond the demands of solar evaporation, and also through the rainy season the drains should be in full activity, to take away all excess of rainfall beyond that which always forms the moisture of the soil; but should it be impracticable to obtain an outfall by a cut, the application of a system of launders must be resorted to, so as to conduct the water from the sump across a portion of the jheel to the most convenient outfall: of course, in that case, the water would require to be lifted by mechanical means from the sump to the launders, which will be elevated sufficiently to have a properly adjusted rate of decline towards the outfall.

There are shallow lakes, some of vast extent, with muddy bottoms and marshy soils, which can be drained, and the recovered land irrigated in a similar manner to those before described. But it may be asked, how can shallow lakes be recommended as objects on which capital should be expended in draining, when the probability is that much neighbouring higher land is lying uncultivated and unoccupied? But the reply to this is, that the drained lands of the lakes or swamp—bottoms—are generally of a far richer and of a more fertile character than the usual run of other land, the irrigation can be effected more easily, the mechanical lift of water in most cases (if artificial means are resorted to) will be much less expensive than would be the case in higher lands, and if the water can be brought there by natural flow, as it often will, the command of the feeding canal will be much greater than can be obtained in any other position.

CHAPTER IX.

ON THE CULTIVATION OF LANDS TOO REMOTE FROM RIVERS TO OBTAIN BY CANALS AN INFLOW OF WATER FOR IRRIGATION.

When lands are situated on great alluvial plains, or on deltas of rivers, or on doabs between rivers, the supply of water for irrigation cannot always be obtained. Under such circumstances cultivation, during dry seasons, soon ceases altogether, unless recourse be had to such water as is impounded in tanks and reservoirs, or raised from wells; in these cases it is requisite to apply some mechanical lift to raise and distribute the water to the higher contiguous land. This lift is now generally obtained by the power of man alone, or by animals working in machines of both rude make and still ruder conception, and from the use of these machines the mechanical results do not equal half the force applied to move them. This is the case in the hot and dry parts of Spain, Italy, Turkey, Syria, Egypt, Arabia, India, China, and other countries where seasons of great drought annually occur; and it is from the want of the application of even this imperfect power, and the great depth of the subterranean water-line, that such vast tracts of uncultivated lands lay waste and barren in many of the countries named above, and in others where rain seldom or never falls.

It is thought by many that the fertilising effect of river water spread over land during flood is alone due to some inherent quality of the water; but such is not the case, for in Lombardy, Egypt, and many other countries where some of the best crops are grown, the water is derived entirely from wells of considerable diameter sunk into an underlying stratum of open gravel, the water being clear and pure, but undoubtedly derivable by indirect and subterraneous means from contiguous rivers, as, for instance, that of the Nile, the level of the water in the wells being governed by the level of the stream; and it may incidentally be observed that the water of the Nile is not more rich in fertile ingredients than that of the river Humber in England, so it may be said of India the crops are often as good where the water is derived from wells as the water obtained where the rivers periodically overflow their banks.*

The existing wells required for irrigation are not of great depth, seldom exceeding from twenty to thirty feet, but are of considerable width, often equal to the depth, and sometimes made oblong, so as to be adapted to the working of whatever rude mechanical arrangements may be employed to lift the water.

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* The amount of fertilising ingredients held in solution in river-water near the junction of the salt and sweet water is very

To employ the well system on a large and more extensive scale of operation, and to fit this system to the purposes of agriculture in so complete a manner that constant and ample crops may nearly at all times be ensured, and to change the present system so far as to employ superior mechanical appliances and improvements for distributing the water, it will be requisite also to adopt at the same time a course of cultivation similar to that previously recommended for the growth of cotton and other produce.

The well, or sump, will require to be constructed of a diameter commensurate with the area to be cultivated and deeper than those now in use, the limit of the diameter being the stability of the inner boundary wall, which retains and gives permanence to the sides of the structure. This wall may, perhaps, average from bottom to top three to eight feet in thickness, and the well may be from fifty to one hundred feet in diameter; the bottom courses, having open joints in the masonry to allow the water freely to percolate through, such a well will (if the previous strata into which it is sunk in be coarse sand or small shingle) admit the infiltration of a considerable volume of water equal to a small river yielding perhaps one million gallons per day. This will afford annually three thousand five hundred tons of water at least to each acre, and after the nearest river is reduced to a minimum flow by continued dry weather, will require near that river one hundred and fifty horse-power; but if at some distance remote from the river, the requisite power will be diminished, because the slope of the subterranean water-level decreases as the river is receded from; consequently, the water will be obtained at less depth and with less expenditure of power. The pumping would be employed from one hundred and fifty to two hundred and twenty days, but this power would be available at all other times for cleaning cotton, scutching flax, and all other purposes which a heavy agricultural production is sure to demand.

If the subterranean water is not too deep, a well or sump such as here referred to may be sunk by cutting a channel of a width of six or eight feet, the line of which may coincide with the circular wall which sustains the sides of the well. This channel must, for the support of the sides, be strutted across during the time the wall is being built, after which the backing may be put in, and the interior space excavated sufficiently deep to give an ample volume of water, the test being made of the quantity of water obtained after the engines have been some time at work in the driest season of the year, during the time of sinking the sump it will be requisite to keep the ground dry by pumping with temporary engines.

When a well or sump of considerable size, but much less than that just described, is required, say of fifty feet diameter, and from thirty to fifty feet deep, a cylinder of brick laid in the best hydraulic cement, and frequently banded horizontally with hoop-iron, may be built on a platform of timber ten inches thick and exactly the shape and width of the wall of the cylinder, which cylinder should taper a little inwards from the bottom, so as to sink into the ground with the least possible friction, the sinking should not commence until the cement is sufficiently hardened all through the work.

The excavation of the interior of the cylinder should be carried on in a very even and equable manner, especially near the walls of the cylinder; but it is still more necessary that the clearing from under the timber should be accomplished with still greater care and regularity. If these precautions are observed, the cylinder will sink evenly, and without sustaining any fracture in the walling of the sides.

Other modifications may be made in the method of constructing wells having wide diameters, such as cutting them to a slope and covering the sides with concrete for some distance down, or by watling them; but such structures are mere temporary expedients; as the foot of such slopes are always drawing in by the infiltration of the water supplying the outdraught, the sides are liable to slide, and the bottom to become obstructed. It will, therefore, be found much the best, and eventually the cheapest, to adopt the best resources of engineering skill in obtaining and applying water to irrigating purposes.

EXPENSE OF IRRIGATION.

The expense incurred for the supply of water to irrigate a given acre of country will be much influenced, first, by the extent of area to be improved, the altitude to which the water will have to be raised, and second, by the extent to which the system is perfected, so as to raise the largest amount of produce from each unit of land.

If the level of a large river is maintained by a great barrage, a vast extent of country will thereby be placed in a favourable position to receive water at the least expense and in the most advantageous manner, for even if an artificial lift be given to the water above the level of the barrage to the level of the land, it will be attended with a moderate expenditure of power, and the cost of barrage may not exceed from five to ten shillings per acre. In addition to which, the great leading canals and the subordinate canals, together with the detail of works for laying on, retaking off, and transferring the superfluous water to other land, will cost from twenty-five to fifty shillings per acre.

The cost of the mechanical arrangements and works for raising and applying water to such lands as are situated above the great canals, and such as are fed from shallow wells, will be from twenty to sixty shillings per acre. This outlay has no reference to the estimate above stated.

The cost of first breaking up the ground by the steam plough, from two feet six inches to three feet deep, will be forty shillings per acre.

The above is the average cost of bringing the land into complete tillage, equal to any European land, and if the first cost of the land and expense of road-making be added, it will represent an outlay of *5l.* 18s. 6d., or, in round numbers, *6l.* per acre, as the cost of the first outlay, but which is not a recurring expenditure, and is inclusive of a portion of the cost of the cultivation required for the first crop, and which is an annual outlay.

The subsequent annual recurring expenses on a cotton crop, after the first year, will be:

	£	s.	d.
Interest on capital sunk as above stated, at 15 per cent. per annum	0	18	0
Cultivation, seeding, and pruning for each crop, inclusive of picking	1	14	0
Irrigation, expenditure, jinning, and packing, including power	2	12	0
	5	4	0

If cotton is grown, the crop will consist of from three hundred to six hundred pounds of merchantable produce; say an average crop of four hundred and fifty pounds will be obtained, which in the country where it is produced ought to be at least worth fourpence per pound.

The above estimate must be viewed irrespective of the present unsettled price of cotton, and as an approximation only to the general value.

The estimated cost for labour is much higher than is now paid in India, whilst the estimated price of the cotton to be produced is low, although there is no reason to believe it will in any respect be inferior in value to the cotton of Egypt.

This cultivation is estimated at two feet six inches to three feet deep, which, according to all previous observation and experience, ought to produce eight or nine hundred pounds of clean cotton, at least, per acre.

This system of culture can be carried on for a cotton crop for three or four years in succession, when advantage will be found in changing the crop, either to that of corn, sugar, flax, or any species of product demanded by the wants of the country. Two crops of grass, or four of Egyptian clover, or one of flax, and one of hemp, can be grown by this means of cultivation in the season succeeding a last cotton crop, if the periodic rain is not too continuous.

In the deltas of the Nile and the Indus, the produce and results will, by improved cultivation, be larger than that above stated, or perhaps greater than is attainable in any other country, because the facility for cultivation in both these countries is very great, and if the ground be copiously and regularly supplied with water, and tilled with care, the crop will be growing every day in the year, without reference to any change in respect to weather, rainfall, or sunshine.

In order to ascertain how far the above estimate of capital required for the establishment of irrigated plantations in India, and capable of competing with those of America for European markets, agrees with the American expenditure, it will be requisite to place the capital of the slave planter in juxtaposition with the proposed Indian outlay and the employment of free labour.

The American planter has first to purchase land, and pay for the clearance of wood, or in case of prairie land he has to drain it, and in both cases it must have a first breaking up in every respect much inferior to that included in the Indian estimate.

The principal item, however, is the capital required for the purchase of slaves. This is a division of expenditure very difficult to estimate, because the planter does not purchase men singly, but generally by whole families; but since the young part is always growing into money, he does not bring them entirely to account of plantation outlay, but estimates only a portion of the family as a requisite expenditure for the renewal of the labouring stock, or field hands. We must, nevertheless, place the account as sunk capital.

A good labouring negro and a part of his family will cost at least 240*l.*, and will do the annual work required by the tillage of from six to ten acres of cotton land, together with the cultivation of such provision land as the family requires. This gives 40*l.* per acre as the outlay for sunk capital, to which must be added buildings, machinery, bullocks, and horses, amounting to 3*l.* 10s. per acre additional.

The account for establishing a plantation would then stand as under:

	Per acre. £	s.	d.
Capital sunk in the purchase of labour . . .	30	0	0
Machines, buildings, and implements . . .	2	0	0
Bullocks and horses	1	10	0
First breaking-up land, fencing, and draining (the last item is not an annually recurring expense)	2	0	0
Total capital	35	10	0
Annual cost:			
Interest on 33*l.* 10s., at 10 per cent. . . .	3	7	0
Annual expenditure on cultivation, and depreciation	1	14	0
	5	1	0

Produce, from 300 to 600 lbs. clean cotton per acre.

Clearly, then, the reason why India has hitherto been unable to compete with the Gulf States of America is entirely attributable to the perennial showers of rain which fall—both frequently and at intervals during the growth of the American cotton plant—to the retentive nature of the soil for receiving water, and yet not retaining too much, as well as to the energetic supervision of the planters, as contrasted with the non-observance of either system, organisation, or agricultural rules in India, together with the almost entire absence of the employment of capital, and the want of a combined system of efficient irrigation, whereby the country could be divided into groups of cultivable areas, under the control of several distributed hydraulic departments of the government. Had this been adopted some years since, and the necessary capital employed, the free Hindoo would have been now effectually competing with the slave labour of America in the various European markets.

Cotton land is now cultivated in India for ten shillings per acre, but such cultivation must not be placed in comparison with the cultivation of either that part of the Gulf States of America, or the system now recommended. The cost of tilling an acre of land, for instance, in the Dharwor district, will stand thus:

	s.	d.
Land (rent per acre)	2	0
Ploughing, weeding, and cleaning between the plants	4	0
Gathering the kupas or unseeded cotton . . .	0	9
Seed for planting	2	0
Total cost per acre	8	9

The resultant crop derived from this species of cultivation in quality is worth only half, and in quantity, on the average of years, would not be more than one-eighth the weight of that produced by American cultivation; but in contradistinction to this it may be stated that in the delta of the Indus an expenditure of one hundred shillings per acre is often incurred for irrigation purposes by animal power, and that land so watered will, from its great productiveness, frequently bring in a rental, including the water supply, equal to one hundred and sixty shillings per acre. Of course several crops are grown in the same year with this outlay for water.

But against the assumption that India could compete with America in supplying to Europe a considerable portion of the cotton required it may be urged that the cost of freight to Europe is so much higher that the balance of profit must remain in favour of the latter. However, for such observations as relate to this division of the question, reference must be made to the article which treats on the commercial transit from Europe to India, by way of Egypt.

CHAPTER X.

OBSERVATIONS ON THE DETAILS OF COTTON CULTIVATION AS PRACTISED IN SEVERAL COUNTRIES.

The cotton-plant will grow, as far as climate is concerned, in all countries within the tropics and as far north as the Mediterranean side of Spain, Italy, Malta, and European Turkey, and southward as far as Victoria, in Australia, and the North Island of New Zealand. It will flourish at the level of the sea, or on elevations of several thousand feet of altitude.

The cotton may be planted in countries subject to annual periodic rainfall; and it will also grow and produce large crops, of good quality, in regions (if well supplied with water) where it never rains.

It will grow on heavy clay soil, or on an open sandy soil, and likewise on such loams as partake of the character of both; or it will produce on the drained jheels, or marshes, of India, the recovered marine mud lands and savannah swamps, when made dry, like those of Guyana, or the prairie soils of the Southern American States.

This plant will commence growing, flourish, and produce a crop in eight months, or it will, under other conditions, require one or two years for its perfection; it will either be an annual, biennial, or a perennial, or its varieties will emerge from a shrub to that of a tree, continuing to grow for fifty years and upwards.

From what has been said it will be perceived that the cotton-plant takes a wide range as respects climate, soil, and rainfall, and possesses great adaptation to new circumstances. It will therefore be at once seen that the failure either in quantity or quality, or in both of these requisites to successful cultivation, is due at particular seasons to the absence of some essential element indispensable to its proper growth, but we see also that by artificial means the deficiency may be supplied, and the balance so important to support the equilibrium of moisture (assimilating with the sustaining material required by the plant) may be maintained, conjointly with the action of the air also circulating through all parts of the cultivated soil.

This deficiency may be caused by the absence of one or several elements requisite to the development of good cultivation.

The first deficiencies of result may arise from too great or too small a quantity of water; the one is corrected by draining, the other by irrigation, and the balance may be maintained by the co-operation of both these processes often acting alternately.

A further deficiency of result may arise from the land being of too dense a character for the roots of plants to penetrate and expand in the earth below the line of tillage.

This can be remedied by deep cultivation, which may consist of trenching by spade-tillage in the small way, or by subsoil ploughing, either by cattle or by steam in the large way; if steam-ploughing is resorted to, then the operation of pulverising the soil may take place to a depth of two to three feet with great advantage.

If these three conditions are brought into action by artificial means, the beneficial agency of the air circulating below the surface will follow as a sequence to the above: of course we must assume that the tropical or semi-tropical solar heat is always co-operating, as the first and active principle by which all the vegetative functions of plants are brought into, and maintained in, full activity; therefore we must conclude that, supposing the conditions of the soil are the same, a crop of cotton can be grown in all countries possessing the proper temperature, provided industry and capital effect the proper systems of draining and irrigation, and also resort to deep ploughing periodically, especially where the texture of the ground is of such a nature as to require this last application.

In the United States of America, especially in Alabama, both soil and climate are well adapted by nature for the growth of the cotton-plant. The land most in favour for this purpose is prairie land, having a damp substratum, an open texture, and great power of retaining moisture, but never capable of retaining wet. This cotton soil has also considerable calcareous matter in its composition: a soil of this description has the power of absorbing gases in an eminent degree, so that in dry seasons, and by some unexplained means, considerable quantities of nitrogenous combinations are undoubtedly condensed in the pores, but this circumstance is not alone common to the cotton districts of America, it is observed to be a characteristic, in a greater or less degree, of all tropical soils.

The American cultivation of cotton generally commences by breaking up the soil in winter at such periods when the ground is not wet. It is divided into sections, or beds, or, as we call them, "lands," of a width varying from four to six feet: these beds are thrown up on each side towards the centre, or list, first struck out. By this course of proceeding the ground is brought into elevated and sloping divisions, by which means the air can act with considerable advantage on the broken soil, until about the month of April, when a seed-furrow is run along the crown of each ridge, into which the cotton-seed is copiously put, the furrow being closed over the seed by a wooden roller, drawn by one horse, much in the same manner as our turnip culture is carried on, and, like it, the superfluous plants are afterwards thinned out. The thinning is repeated several times, so as to ascertain which are the strongest and best plants; and when the selection is ultimately accomplished there will only remain one plant in a given area, which, like our turnip and mangold culture, requires a space for one root alone to occupy. Up to this time the ground is kept clean, and if the culture be perfect many cleanings by the hoe and plough have taken place. This is continued until the spread of young foliage overshadows the ground, and prevents the further growth of weeds and grass. About six to ten thousand plants are grown on one acre, but fewer are required when the ground is of very good quality; and where the roots can strike out in all directions, about three hundred cubic yards of earth are occupied by roots on one acre; but if deep ploughing was resorted to, as recommended in this report, the roots of the plants would occupy at least from one thousand five hundred to two thousand cubic yards on a similar area. The cotton-plants in the States will commence giving bolls about the middle of August, and continue to furnish employment to the pickers until the winter sets in; then the operation of gathering is entirely ended, and the plant withers; but on account of the absence of frost in countries more south than the States, the plant does not cease growing, but remains perennial, and is only renewed after having survived several years of productiveness.

The mode of cultivating the cotton-plant in Egypt is like that of America, so far as concerns the preparation of the soil and the mode of planting; but with the exception of the supply of water given to the plant during high Nile all the rest of the water required for the crop is lifted artificially to the surface of the ground. The ploughing of the cotton land in Egypt is much inferior to that of America, and the subsequent working the soil between the rows much more so, and is sometimes altogether neglected. If deep ploughing was resorted to in Egypt, and subsequent care of cultivation adopted, the produce of cotton from a given area would exceed that of America from a similar area of land, whilst the quality, if we except that produced on the islands and coast of Georgia, would be altogether superior to that of the States.

The ordinary and general system of cotton cultivation in India is somewhat various, but, nevertheless, one description of the operation will apply to all parts of the country (the deviation in particular districts relates only to minor details), the cultivation being entirely dependent on the periodic monsoons, and the quantity of the water which can be then retained in the ground to supply moisture after the rainy season has passed away. The ploughing is of a very imperfect and superficial character; the cotton-seed is geseeds, the object being to cover the ground with vegetation, so as to lessen the amount of evaporation. It is an object also to obtain a crop of some other kind intermediately, in case the cotton crop should fail altogether; and often conjointly with cotton other productions are gathered. Should the dry season set in early the plant will then soon feel the effect of the loss of moisture, so much so that in India it is requisite to rely on an indigenous variety of plant which possesses a long tap-root with a small stem, and which arrives at full growth prematurely; and although the plant will withstand the vicissitudes of an Indian climate better than any other, its yield in cotton is so small (being only from thirty, to one hundred pounds weight per acre) that it would not be worth cultivating if labour and the cost of land were not very low, and the capital required to be invested in this shallow tillage exceedingly small.

The crop whilst growing is never cleaned, as in the Southern States of America. The seeds are thrown over the ground in an irregular broadcast manner, patches of land are often bare, the thinning is much neglected, and if the periodic dry weather begins somewhat early, or the heat is more than usually intense, the entire crop will be lost, or will be so inferior from premature drying, and the consequent difficulty of cleaning is so great that it often will not pay for the trouble of gathering, and is, consequently, left on the ground.

In some parts of India the state of things is, to some extent, better than that described, but even in the best-cultivated territory the product exceeds very little that above stated; yet it is from culture so carried on that England is at this period looking for that supply which is expected to interpose so as to fill the void in the markets of Europe caused by American difficulties.

A great number of experiments have been made to introduce the American system of cotton cultivation into India, but as no proper estimate was made beforehand of the deficiency of moisture at certain periods of the year, and as no adequate method was devised to supply by mechanical means that deficiency, of course, as a whole, these experiments failed, except so far as relates to the advantage which has been derived from the introduction of seeds and the consequent new varieties of plants which have been introduced into India.

The cotton-plant cannot become a perennial in India except near a supply of subterranean water within reach of capillary attraction, because in the dry season the ground becomes parched to a depth greater than that of the deepest root; but as cotton is grown in Guiana and the Brazils as a perennial, it is requisite to draw some attention to the peculiarities of cultivation there, in order to see how far the cotton-plant in India may be so cultivated.

It has before been explained that cotton is grown on the coast of Guiana to a considerable extent as well as in the Brazils, and in both countries along the verges of rivers, but chiefly near the sea. The soil is often a rich consolidated mud, brought down by rivers or left by the retrocession of the sea, and is so situated that the supply of water required by the plant in dry seasons is obtained by canals, which also carry off the superfluous water in the wet seasons. By these means the ground is never dry nor is it too wet, beyond holding that requisite moisture which rises to the surface by capillary attraction only; the earth is also cooled by evaporation, and vegetation is at all seasons fresh and green, although so near the equator that we might, from that circumstance, expect a different result during the annual dry weather.

In Guiana the land until recently has been tilled by the spade only, the draining also being effected by the same implement. The seed is dropped into cylindric holes, eighteen inches deep, prepared for the purpose, and filled with loose earth, half an inch being put over the seeds;[*] the plants are afterwards thinned out so as to leave only one tree. The distances of one to another depends on the goodness of the soil: five or six feet may be considered the average space. The lines laid out are sometimes thus:

● ● ●

● ● ●

so that straight lines are seen in four directions without the spectator moving, and as the trees are permitted to grow for four or five years before renewal, much care is taken in preserving the direction of these lines. Any deficiency in the trees is re-supplied by the transfer of new plants from seed-beds.

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[*] The holes are called hills, because the ground is subsequently drawn up towards the plants by the hoes.

Beds are formed from thirty to forty feet wide, and drained by channels into the side cuts of the estate; the beds are slightly raised in the middle, so as to prevent rain-water stagnating on the surface, and which is rightly considered to have a most injurious effect on the healthful condition of the cotton-plant.

More recently the row-system has been introduced, and ridges are formed instead of beds—that is to say, the width of the rows of trees are wider in one direction than the separation is in the other; for instance, five or six feet may be the space between the several rows, and from eighteen inches to three feet may separate the trees from each other.

All the cultivated lands on the Guiana coast are situated within the influences of the sea air, and saline matter is contained in the soil; but should it become too much exhausted, the planter resorts to marine inundation, by which much salt and other fertilising matter is again restored.

Two crops of cotton are gathered in the year in this country, but as the second crop comes to maturity between two rain seasons it is often injured by a superabundance of water and a want of sunshine. If a more perfect and deeper drainage was adopted even in this country a crop of from six hundred to eight hundred pounds of long-stapled clean cotton might always be calculated upon, and disease in the plants would in a great measure be avoided.

The seed is put in the ground, and at the second year of the growth of the shrub it is pruned, trimmed, and, like the coffee-plant, it is topped at about four feet from the ground; pruning is annually resorted to afterwards.

It has before been observed that in this country all superfluous water is taken from the soil by cuts and drains, which are maintained in the hot, dry weather at a proper level, and so as to again restore the requisite moisture abstracted by evaporation from the soil after the rains have ceased.

The system of cultivation for cotton on this coast is, perhaps, the most perfect in use, and if the supply of labour was more abundant, no doubt this territory would furnish a large proportion of the long-stapled cotton required; already has great advantage been found by the introduction of mechanical power for draining the land, and thus gaining a command [illegible] maintaining the cultivable water-level so indispensable for ensuring the health and vigour of cotton-plants.*

Near the shores of Georgia and South Carolina a number of islands are situated, with a soil of an alluvial character. The mainland is of the same quality of soil, extending from ten to fifteen miles inland, and stretching along the coast perhaps one hundred and fifty to two hundred miles, north and south. On this extent of territory the Sea Island cotton is cultivated, along with other agricultural productions, as an alternative crop.

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* Messrs. Easton and Amos, Mr. Hawkley and myself, made reports several years since on the drainage of this country, beyond which I was personally acquainted with this country many years since.

It is well known that this long-stapled fine cotton is the most valuable wool brought to the European markets; and as any transference for cultivation of the seed from this locality to any other is attended, with few exceptions, with an immediate deterioration of quality, it will be worth while to seek for the probable cause which leads to this result.

The cultivation of Sea Island cotton is, in many essential points, different to that of any other tillage required for the growth of this staple; the soil is different, and the climate exercises some considerable effect on the length and quality of the wool. We have, therefore, three essential points for consideration, and to which inquiry must be directed, in order to illustrate the causes which lead to the production of wool of a quality which cannot, *so far*, be approached in quality.

The soil where the Sea Island cotton is grown is a finely-divided light, open, sandy deposit of marine silt, having but little elevation above the present sea-level, consequently the root of the plant can extend in all directions, and throw out its ramifications of roots to a greater extent than in most other soils; in addition to which, the land having been marsh, water is always within reach by natural means for the supply required by capillary dispersion.

All lands recovered from the sea, and which were formed by tranquil deposition, possess in an eminent degree all the elements for the production and sustenance of vegetable life. The soils forming the coast, and most of the islands where the long-stapled cotton is grown, are of this character;* and although now much exhausted from continued culture, through a long series of years, and without being adequately manured, is still a country whose soil undoubtedly receives from nature the benefit of many concurrent advantages essential for the prosecution of successful tillage; and should the planters themselves ever experience the full benefit and advantage of refreshing the soil by a restoration of the elements which successive crops have taken away, and when they have learned the art of obtaining a more perfect command of the water intersecting their fields and plantations, their country will be, according to its area, as eminent for quantity as it has heretofore been celebrated for its quality of cotton.

The saline ingredients in the soil no doubt contribute largely to the production of long-staple cotton, and from circumstances which have not yet been explained, it is certain that plants in hot countries flourish where a greater amount of soluble salts are contained in the soil than would be admissible in the agricultural system of a colder climate.

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* Edisto is the principal island where the long-staple cotton is grown.

The cotton lands of this region have originally been marshes formed by sea deposit, and it is now found requisite to manure the older plantations. Of all the materials which can be put on the ground, salt marsh mud is the most efficacious for supporting a cotton crop; of course for corn, and other farm crops alternately grown on the same ground, stable and pen manures are also resorted to as fertilisers; but when the land is fallowed moveable pens are put on it, to save the labour of transporting the manure to the field. Here, then, we see a mixture of the ordinary operations of agriculture united with cotton cultivation, without which the celebrated Sea Island cotton could not be produced in quantity, because even if the land was tilled for the first time, ten crops of cotton taken in succession would exhaust it. From this it may be deduced that the soil of this coast and islands possesses no other peculiarity of quality except its marine origin, and that its fertility can only be maintained by the application of a considerable quantity of similar soil, possessing in a more concentrated form the same fertile qualities as those originally belonging to the soil of the cultivated fields; and as these fertile qualities consist of oceanic deposits, the quality of this land for producing fine cotton must, in a great degree, be owing to the sustenance derived originally from the sea, and this seems to agree with the fact that all fibre-producing plants flourish best in rich lands, originally formed by fluviatile depositions, if interspersed with sufficient fine sand to keep the texture open and porous. We may, therefore, conclude that Sea Island cotton-land owes its perfection and limit in quantity to—

1st. Its marine origin, and its combination with the requisite quantity of soluble salt, and the elements of vegetation.

2nd. Its vicinity to the sea, the air of which possesses certain qualities conducive to the growth of long-staple cotton, and, further, it preserves a greater degree of atmospheric equability than exists in places more remote from oceanic influences; at the same time the temperature of the sea being high along this coast, still further preserves this equability of the air whilst the plant is growing.

3rd. The texture of the ground being open, the delicate root of the Sea Island cotton-plant can strike downwards and sideways in every direction, even to a depth below the operation of tillage, by which means soluble food is taken up by the plant from a greater area than is attainable in a more impervious and less penetrable soil; besides which, from the level nature of the land, and the moderate depth of the water, the supply of moisture is equably maintained at all seasons, whilst the drainage is nearly perfect, except as to depth of the drains and control of the water.

4th. The limited quantity of fibre obtainable from a given area of land, as compared with the other American cotton states, is caused by the want of deeper ploughing, more perfect drainage, and too great a limit to the application of salt marsh mud manure (but which, however, requires to be put on the ground with a supply of at least ten times its weight of sweet water, as an irrigating medium). To these concurring advantages, which now exist, is undoubtedly due the superior quality of Sea Island cotton. By the application of improvements, which might still further be added, an increased quantity in weight of wool may yet be further obtained.

The tillage of the soil for the growth of this cotton-plant is performed on the islands chiefly by the spade, and on the mainland by the plough. On the islands the ground is laid out in beds, the rows being five feet apart, and each plant is separated the contrary way, by a space of fourteen to twenty-four inches. The young plants are grown in seed beds, and are put out on the cultivated beds at the beginning of June, and each succeeding year the rows are alternated, that is to say, the line of trees will form the alleys the succeeding crop.

On the mainland the ground is turned over by the plough so as to form ridges of about five feet wide and eight or ten inches high. This is effected by throwing the furrow-slice well up to the centre, and so as to form as great a slope as possible towards the furrow which divides each bed. The land is intersected into acre lengths, which often form the drain for exhausting the water from between the ridges, unless the ground is situated high and is of a porous nature, in which case the cross drain is dispensed with; a shallow furrow is run along the top of the ridge about three inches deep, into which the seed is put, and then covered over with earth to a depth of two or sometimes three inches, according to season. Generally three weedings and thinnings succeed each other, until the best plants only are left a distance of about twenty to twenty-four inches asunder in the row, the hoes having been in the mean time made use of not only to clear the weeds, but also to bring the soil well round their stems, it being necessary to obtain this support, because in the vicinity of the sea the fresh breeze is liable to blow down and injure the tender plant.

Many contingencies occur to retard or injure the growth of Sea Island cotton. Winds and rains frequently make their influence felt, or interpose to retard the operations of cultivation and the gathering of the crop. A great want of shelter is felt from the absence of tree rows between the farms; for in places where land is of little value, and where the purchase of labour is dear, we need not look for the maintenance of this description of shelter, however much it may be desired, especially in a country where the great object is directed to the destruction of forests, and not to the planting of trees, or forming arborescent boundaries to farms.

Having said this much on the growth of Sea Island cotton, I will endeavour to draw a short comparison to show the analogy which exists between the coasts of Georgia and Carolina and the coast of a large part of India. I have before referred to it in this report, and

I allude to it again, because some years since I was struck with the similarity of the conditions which appertain to the soils of both countries.

Along the coast of Madras from Cape Comorin, and extending to the sunderbunds of Bengal, the low-lying shore is, like that of Georgia and Carolina, composed of recent alluvial sea mud, or earths derived from recent oceanic deposit. Some of this land is occasionally, at the periods of high tides, covered by the sea, by which means the government of India is enabled to manufacture the salt required for the use of the country. Farther inland, forming a belt parallel to the coast, the land is slightly higher, but capable of being irrigated, like the low-lying marshes just now spoken of, and in all conditions the coast-land is similar to that of Carolina and Georgia, except in the long period of dry weather, and which appertains to the climate of India. It is on that account that irrigation is indispensable, but when adopted, the favourable conditions of the coast and delta land of India will not only be equal in all respects to the Sea Island districts, but will exceed them on account of the prolonged duration of the period of sunshine, the command of water, the power of growing the plant as a perennial (because of the absence of frost), and, lastly, the ground is now fresh and unexhausted, and an unlimited amount of free labour is available to be employed in the details of cultivation; besides, if we incidentally draw attention to the great advantage which may be obtained by deep steam-ploughing, we may almost conclude that the quantity of cotton which may ultimately be obtained per acre from the coasts of India will equal in amount that obtained from a similar area of the land of the Mississippi, and the quality may eventually compete in the European markets with the produce of the Sea Island districts.

The same observations apply equally to the coast of Bombay and the delta of the Indus, so far as concerns the lands which are, or have been, covered with river or sea deposits.

It has been considered desirable in a concise manner to describe five systems of cultivation carried on in five several countries, in order to show that cotton is grown under varying circumstances and treatment, with results differing only in proportion as culture, climate, rainfall, and the local and chemical conditions of the soils vary in each respectively. This may be seen by the following statement of produce and comparative value:

Produce per acre in clean cotton.		Average proportional value per lb.	
	lbs. lbs.	*s.*	*d.*
States of America	300 to 600	0	8
Ditto ditto Sea Island	150 to 300	1	6
Egypt	300 to 400	0	8½
India	30 to 150	0	5
Guiana, West India, Brazils, &c.	250 to 600*	0	7½

From the above approximate statement it will be seen that good tillage and a favourable condition for maintaining moisture in the soil for the purpose of cultivation is indispensable, and which condition exists either naturally or is applied artificially, and, combined with a system of drawing off all the superfluity of water during rains, these constitute the chief means supplied by either nature or art, or both conjunctively, to produce a result as represented by the three to six hundred pounds of cotton obtained in Egypt and the American States, as contrasted with the thirty to one hundred and fifty pounds, being the utmost quantity produced in any part of the Indian Empire.

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* The above is estimated as the produce when the land is cultivated in the best manner according to the custom of each country respectively.

The conclusion which may be arrived at is this: If you drain correctly, supply water judiciously, and plough deeply, then the result of Indian cultivation may in weight even exceed that of the States of America, whilst the quality will most probably be equal to that of Sea Island cotton.

It has before been stated that in several countries the cotton-plant is perennial, but cannot now be maintained as such in India, because of the excessive dry seasons occurring between the monsoons, and which exhaust all moisture from the ground to some distance below the root, thereby cutting off all sustenance from the plant; but if the requisite water supply is at all times regulated through the year, alternately draining and (at a proper period after the rains have ceased) irrigating the soil, the plant will be always growing, and will, of course, require pruning when it is desirable, by which means it will be prevented from bearing fruit out of season; the plant may then become perennial, and all cultivation, except that of cleaning, filling up, and loosening the soil between the rows, will cease until the next planting season, which may be at intervals of from three to six years.

It is not imperative that the plant should be retained in the ground more than one year, if on practice it is found in any particular soil to be more advantageous to grow it as an annual.

As often as the trees are pruned, and after every crop is gathered, the cuttings and the cotton seed together, with all weeds, grass, and extraneous vegetables, should be put into deep furrows run between the rows for that purpose, so as to maintain, as far as possible, the fertility of the soil, and to keep it open to assist the action of the air upon it.

The application of a system of planting in some degree approaching that of America will be found advantageous where the ground is side-lying, or is upland, or has any slope; but where it is on a level, or a series of levels, then the Guiana system will be found preferable, especially where the ground is very open, and does not require much ploughing; but we must always suppose that a system of draining, irrigating, and, where needed, embanking, will be resorted to in every case.

If the cotton-plant is grown as a perennial, then it should be topped either before or at the end of the first crop; but should it be grown as an annual, then it should have a portion of the stem taken off at an early period, to cause lateral growth, and if wood is too rapidly grown, pruning both annual and perennial plants will be found advantageous to check the exuberance of growth, and to allow air and light to enter and circulate amongst the trees, and traverse all parts of the surface of the ground.

If the ground is clean, and free from extraneous vegetation, so that the sun and air can act upon it, great evaporation from the soil and by the leaf of the plant will take place, and also at the same time this evaporation from the soil by radiation will cause an immense absorption of heat to form vapour. The absorption of this heat causes the ground again to cool considerably, so much so as to re-condense a portion of the vapour after sunset, by which the fields are enveloped in those invisible aqueous exhalations which are either re-absorbed by the earth or settle on vegetable surface, and form dew.

The increased power of evaporation given to the plant by the air circulating amongst the growing crop, and by the act of pruning, will be most amply repaid by the increase, both in quantity and quality, of the wool. By evaporation the juices of the plant will be better fitted to produce more perfected fruit and seed, because by the exhalation of moisture from the leaf the quantity of sap will be increased. And should all those conditions which have been frequently insisted upon be brought into full activity, and all the various mechanical arrangements made, and which have been described as necessary auxiliaries of perfect cultivation, then the full advantage to be derived from powerful sunshine and light will be found to exist, not only in the increase of the product obtained, but also in its superior quality, it being necessary at all times to bear in mind that there cannot be too much sunshine falling on every leaf of the plant when making progress during the vigour of its growth. Nor can the advantages to be derived from keeping the exact equipoise between moisture derived from irrigation and the dissipation of that moisture through the soil by solar evaporation, be more exemplified than by referring to the fact that if in India all these means are employed in future, the crop may be kept growing every month in the year, so that the full period of sunshine in that country will be available, not only for perfecting the plant, but, if necessary, also for continuing its productiveness through the whole period of either one or a series of years, instead of, as now, maintaining the growth for a few months only.

The cotton-plant is liable to many contingencies, derivable from too great a supply of water, as well as from the want of that element, and also from the attacks of insects and worms. The cure of both the two former deteriorating conditions may be attained by the application of the hydraulic works which have been described; the latter may in a great measure be avoided by strict attention being paid to clearing the ground from weeds, and sometimes soaking it by the irrigating process for a few hours, and then as suddenly making it dry again, insect life in the ground will be destroyed; and further, by extending to the whole area cultivated such a periodic inspection as will insure the detection in any portion of the soil of any surcharge of water, to an extent which would be indicated by the term wet, in contradistinction to moist—for I have always observed that when the soil is too wet or too dry, or when any other countervailing cause makes the plant become sickly, certain worms will attack the wood, and other insects the leaves, and which worms and insects would not have commenced their ravages had the plant been in full vigour and activity of growth, and had the sap been circulating freely through stem and leaf; and further, respecting the ravages committed sometimes on the leaf by caterpillars, the disaster will be diminished, or altogether removed, by judicious pruning, so as to allow the sun to act freely on all parts of the tree, it being necessary that not only this insect, but many others, should seek shelter from the mid-day sun amongst the most exuberant leaves.

It is by watching the changes which take place during the progress of the plant to its maturity that the exact line of procedure will be understood, and from which rules may be established, and it will be well for both the engineer who constructs and afterwards controls the hydraulic work, as well as the planter who directs both the elaborations of the soil and the collection of the crops, that each respectively study with minute care, and note and register all circumstances which relate to local rainfall, the temperature of the air and soil at and below the surface of the ground to a depth of at least four feet; and further, the weight of the atmosphere should also be observed; it will then be soon found that these observations, simple in themselves, and easy of application, bear greatly on all circumstances connected with the progress of tropical crops under cultivation.

During the progress of this inquiry, and the exposition of those views, which bear on the various questions under consideration, the prominent objects have related chiefly to the improvements connected with the cultivation of cotton, and has had especial reference to India as the chief locality where those improvements would not only be established with the most extensive effect, but where a great national result would accrue from the adoption of a general and improved system of cultivation. It must not therefore be concluded that these improvements and the consequent increase in quantity of produce would alone appertain to the production of cotton; on the contrary, every cultivated crop grown in that country would be alike improved by the adoption of the same means, and in a similar ratio. The cost of production would be lessened, and the quality and value enhanced; and without doubt it may be stated that even in the Southern States of America the adoption of a perfect system of drainage, especially on the low-lying savannahs and swampy grounds near the sea-coast, would produce a like result by diminishing the amount of labour employed and the cost incurred in the production of even an increased quantity of crops.

In describing the details of the best system of cultivating large areas of country which can be recommended for adoption in India for the growth of cotton, it is necessary to state that the system now to be described must be considered as general, and subject to such modification as may be required by variation in soil, climate, and amount of rainfall, together with such other local influences as may bear upon the question.

It is assumed that steam-ploughing will be brought into active operation for the first course of cultivation. This ploughing by steam must be viewed as equivalent to the operations of spade husbandry, by which the ground is trenched two feet or two feet six inches deep.

After the land has been so broken by the plough, and pulverised by the action of the air, the ordinary reploughing may be commenced by forming the ground into beds from three to five feet wide, leaving a deep furrow between them. This latitude of width has reference to the expected size of the plant, as well as to any decision which may be come to relative to the plant being treated as an annual, biennial, or perennial.

The land, being formed into beds (higher in the middle from being lifted, by turning the furrow-slices towards the centre of the bed), may then be gone over with narrow, heavy harrows, fitted with cutting tines of a lozenge shape, which will penetrate and slice the ground to a considerable depth, and fit it to receive the seed.

There are three modes of planting the seed: either by depositing them by means of a drilling-machine on the centre of the ridges or periodically dropping the seed by a drill-dibble, so modified as to deposit ten seeds in one circular spot of small diameter, one foot three inches to three feet apart, or, lastly, by making holes at intervals of from one foot three inches to two feet, in case the ground is not rich or expected to bear a heavy crop. In these holes the seeds may be placed at a moderate depth of one and a half to two inches, and be then covered over with a layer of earth. All or any of this modification in planting must depend on those local circumstances relating to the texture of the soil, which have often been referred to before. After the plants are well up, and possess a developed shape—that is to say, having three joints or succession of leaves—they should be thinned to three separate plants standing in a triangle, thus ● ● ● or if sown in drills, thus ●●● ●●● ●●● After a short time it will be seen which of these three plants is the strongest; then the weakest one must be cut away, and so on with the next, leaving ultimately only a single stem, which will form, in plantation phraseology, "the stand." In the operations of attending to the infant plant a sharp, thin steel-bladed hoe should be employed in scraping and cutting away all grass and weeds surrounding the plant; the operations of the hoe must be employed as often as the weeds appear. When the stand of plants have attained some growth, the broad duck's-foot cultivator may be used down the alleys, also some earth may now be turned towards the stands by what in the American cotton states is termed a bull's-tongue plough. This plough may be better realised by supposing it to be represented by a sharp, well-formed Kentish turn-rest, and to be made of all iron instead of wood, and iron very slim, sharp, and light. The operations by this plough will be that of raising the ground, and at the same time fracturing it, so that the air is let into the earth; and by the same means a small quantity of soil will be turned towards the stands of trees. As the ridges rise higher by this disturbance of soil, the hand-hoeing will draw the grass and weeds to the open centre furrow, and where they will decay; these stirrings by the plough or other instruments should be repeated every ten or fourteen days, for it must never be lost sight of that letting in the air and clearing the land are so essential that no profitable cultivation can be carried on unless it is strictly observed.

There are especial precautions to be carefully kept in view in the early stages of cotton cultivation. These are, first, to keep the stands in as straight a line as it is possible to lay them out; this may be accomplished by setting out the beds with great care, and marking the width of the centre ridge by exact measurement; and whether the continuous drill or the drop drill be used, the lead of the draught animal should be in a perfect straight line. This straight line is of value for inspection, for ventilation, and for the convenience of the passing and repassing of man and animals between the rows.

These straight lines in most parts of India should be, as far as convenient, laid out easterly and westerly, by which means the stands will not shade each other during the early stages of their growth, but farther from the equator, more north and south.*

And, lastly, in thinning the young plants, and cleaning the ground from weeds and grass, every precaution should be observed so that no injury is inflicted on the stem, for if it is maimed to however small an extent, the powers of the plant to produce fruit will be permanently diminished.

Except in the early growth of the stands it will not be necessary to draw any other earth towards the trees than that of slightly turning it in that direction, whilst stirring the soil by the plough between the rows, in fact, the cleaning of the weeds, hoes will draw a portion of the ground in a contrary direction towards the centre furrow, so that by the time the crop becomes ripe the ground will be again nearly level.

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* The object of this observation is to draw attention to the desirability of allowing sunshine to fall unembarrassedly down the alleys; sometimes the lines are for this purpose set out north and south—Spain for instance, and north of Georgia.

This routine of cultivation is, to a considerable extent, contrary to the American system, on account of there being no necessity (if deep tillage is adopted in India) to ridge up by the plough and gather earth round the plant by the hoe in the manner as practised by the American planters, whilst the system here recommended is based on the necessity that for arborescent cultivation in India from two to two feet six inches depth of ploughing or trenching is required. Even in America itself the necessity of deep ploughing and manuring is acknowledged by the improving cultivators of that cotton-growing country.

As the skim-plough, the cultivators, and the weed-harrows will in turn be used in the progress of growing the cotton crop, it is important that no implement should be allowed to cut the ground too near the rows of plants. This precaution is especially necessary to be observed on account of the stands having a disposition to throw out roots laterally and near the surface of the ground, and, notwithstanding its deep tap root, no doubt exists but that these superficial roots play an important part in the vegetable economy of the plant, either to obtain air or carbonic acid gas, or other matter essential to the growth, sustenance, and perfection of the plant. But there is no data on which to decide this question; at all events, to touch or cut off any of the fine felimentatious spongioles would be extremely injudicious and detrimental.

It has been considered necessary to put forward many directions and precautions respecting the cotton-plant in its immature state, because at that early period it is very tender, and without the application of these agricultural observances the full amount of due result need not be looked for. After the stem of the plant has obtained a hardening of the bark, it will with moisture become tenacious and enduring; and although many necessary details of cultural manipulation are here brought prominently forward and insisted upon as essential to proper progress, yet they altogether will not increase to any serious degree either the labour or expense. System, combined with mechanical skill, with the co-operation of tractable, industrious, and observant workmen, and the employment of well cared-for farm animals, will accomplish all without demanding the employment of any serious amount of human labour in the various divisions of tillage.

If all the details are observed the plant will attain a maturity of growth and an expansion of branch, which will shade the ground, and the further growth of weeds will be arrested. Whether it will be necessary to top or prune the plant will depend on the height and the exuberance of the lateral branches, and to some extent on the decision in respect to the plant being maintained as a perennial.

If the plant is cultivated as a perennial, in the second year the material composed of decayed vegetation, which will be taken from time to time from the surface of the beds, and deposited in the centre furrow, or drain, between the beds, must for the ensuing crop be dug out and carefully placed against and round the standing plants, in a shallow trench dug for the purpose, and in which trench, if the ground is not naturally rich, the seed obtained from the first year's crop in a fermented state should also be put, and the whole covered up with soil, by which means a considerable amount of nourishment will be provided for the second year's crop. The ploughing and shallow subsoil ploughing below the bottom of the ordinary furrow, by the bull's-tongue plough, as described under the article on ploughing, must again be performed, and all the weedings, scarifying, and other operations, should again be pursued in a less degree, but in the same manner as is adverted to as being necessary for the production of the first crop.

But should it be found more advantageous to cultivate the cotton-plant as an annual, then two wide and deep parallel furrows should be made, at a distance of three feet from each other, leaving the furrow, which has divided the beds in the centre between the two new furrows; the material taken from the two furrows should be turned over towards the old furrow, not only to cover up the vegetable matter therein collected, but to form the ridge for the new row of stands. In these two parallel furrows, the stems and roots of the cotton-plants which have furnished the first crops must be buried with the fermented cotton-seed, by turning over the furrows towards the new centre, which will become the future ridge, until the whole field is ploughed. From this it will be seen that the young second year's plants will send their early roots into fresh soil, and obtain fertile sustenance from part of the former crop and at an early period of the plants' growth, which is a very important consideration, and next, the old plants will for a short time keep the ground open not far from the rows; this, and by subsequent decay, will allow the roots to spread laterally, and obtain a fitting sustenance.

Should cotton cultivation be carried on along and near the sea-coast of India, it may most probably be necessary to raise on the boundary borders of plantations quick-growing trees, to shelter from the force of the winds the stems of the cotton-plants in the event of their being cultivated as perennials. It will likewise be requisite, whether cultivating annuals or perennials, to draw the earth round the stems in conical mounds—or, as they are called, hills—in order to give the plants the largest amount of support during windy weather.

In regard to irrigating the ground the subject has been treated of before; it is only necessary now to state that divisional limits forming the fields should be one hundred and five feet square, so as to form the several plots into acres. This boundary being the drain, or irrigating canal—according to season—the water would be made occasionally to rise sufficiently high to fill the furrows in the alleys between the rows, but not to stand at that height permanently. Where the ground is very porous then other arrangements for putting on the water must be resorted to, as has been described before.

The system of cultivating cotton, which it is believed is best adapted for India, having been described in all its branches, this part of the subject naturally concludes at this point, because this report only extends to the description of those processes by which the ground may be prepared, and the plant made to grow and bear fruit; all subsequent questions, having reference to gathering, cleaning, and packing the crops, being entirely a separate department of industry, and which can be better treated of by others.

CHAPTER XI.

THE EFFECT PRODUCED AS REGARDS TEMPERATURE BY CONTINUOUSLY SUPPLYING THE SURFACE OF LAND WITH MOISTURE.

MOISTURE is rapidly evaporated, especially in the tropics, by the action of solar heat, and that action is further increased by the motion of the atmosphere.

Water cannot be converted into vapour either from the surface of the leaves of growing plants, or the surface of the earth, unless it has absorbed upwards of six times the amount of the specific heat it possesses at the moment preceding the dispersion of the vapour from the ground.

The heat so absorbed is called latent heat, and is obtained partly from the sun's rays, partly abstracted from the ground, and partly from vegetable surfaces.

Evaporation is also increased when the air does not hold in combination an amount of moisture commensurate with its indicated temperature, and it is still further increased when the weight of the air is diminished. We thus see the reason why the temperature of plants and the surface of moist ground is to a less extent increased in temperature by exposure to the sun's rays than bodies giving off water by evaporation, because all these causes which conduce to the increase of evaporation also put in action the physical law, which demands that before vapour can be formed the water from which it is derived shall absorb from contiguous bodies that amount of caloric which the formation of latent heat requires.

The cooling of the surface of the earth by the process of gradual evaporation will at night react, because of the cessation of the sun's heat, but the radiation from the ground of absorbed heat and vapour will, nevertheless, for some time continue; but as temperature will, during the progress of the night, be diminished, a partial condensation will afterwards take place, and dew will by then be formed; the deposition of dew will be greatly increased when the air is extremely dry, at which time the evaporation from moist soils is so large that at night the thermomatic state of air, near the surface of the ground, will sometimes in warm countries approximate nearly to the point of freezing. Again, when the air is surcharged with moisture, and passes over cool surfaces of moist ground, a precipitation of minute and undistinguishable drops of moisture takes place, and then latent heat is liberated; and to this last circumstance is owing the general remark that moist water-fog weather is, even in winter, mostly associated with considerable warmth.

As the difference of temperature of the air in the night is lower than that of the day, sometimes to the extent of 20 deg. of Fahrenheit's thermometer, the air in the ground will be condensed by night, and expanded again during the day in the like proportion. If to this we add the movement of water in the soil, to replace in the void the water taken away by evaporation, we shall see by these two circumstances alone that no cessation, either by night or day, takes place in those operations of nature which effect the slow but needful chemical changes in the ground so continuously required to give the supply which growing vegetation demands.

If we apply the facts here adduced, we must perceive how important it is that moisture should always be existing in the ground, not only to supply the plants with the aqueous material necessary to support continuous evaporation, but at the same time to reduce, by the radiation of that vapour, the immediate temperature of the air which surrounds all vegetable surfaces; for if the cooling of the ground as well as the surface of leaves was not maintained by radiation, in combination with the absorption of heat, to form the latent heat of vapour, plants would instantaneously die by the effect of solar heat alone.

It is to this cooling effect that grass or plants covering the ground about the roots of cotton-trees, unless removed, prevents the fruit from maturing, and causes the loss of crops. And it may be observed that in America the smaller planters who are short-handed, by leaving the growing grass between the trees, do not derive half the produce from the soil which the larger and better cultivators obtain. On the contrary, in India the cultivator of cotton often sows other crops on the same ground and at the same time, so as not to retain, by the cooling of their leaves, too great an amount of evaporation, because irrigation water is not often to be obtained. If this was not done, the probability would be that the plant would prematurely wither, and from the small crop, perhaps, there would not be obtained a sufficiency of seed for the next year. The American planter, nevertheless, is desirous of having the ground covered with the branches of the cotton-tree when it arrives at its full height, so as to cut off at the proper time the sunshine from the ground, whereby the grass is prevented from growing, and the moisture from the ground too rapidly evaporating; but when perfect systems of irrigation are introduced in India, the interlocking of the branches of the trees, so much desired in autumn by the American planter, will not be required by the Indian cultivator, because continued access of moisture will be ensured, the crop may continue to be reaped until the next monsoon prevents the further ripening of the bolls.

CHAPTER XII.

ON MAINTAINING THE CONSTANT FERTILITY OF LAND, AND THE EFFECT PRODUCED FROM MECHANICAL DISTURBANCE OF THE SOIL BY DIGGING OR PLOUGHING, AND BY IRRIGATION.

IF the earth is not disturbed, the air cannot circulate through it to any great extent; consequently, a soil, although capable of growing useful crops, almost remains inert, except so far as producing trees, shrubs, grass, and plants, fitted by nature to clothe the ground with wild verdure.

The same soil, if broken up, that is to say, divided in such a manner that innumerable surfaces are created, and spaces left for air to occupy, so as to act upon and combine with each particle, as well as with all the ingredients therein contained, will become tractable, active, and fertile, such a soil then constitutes what is called cultivated land, the extent of its fertility being often measurable by the amount of elaboration bestowed upon it; or, in other words, the extent of action permitted to the air by the mechanical subdivision of the soil will, with the required manure, in a great degree indicate the amount of vegetable return which may be expected from it; and if the soils so subdivided are acted upon by air and continuously moistened by water, will then give up gradually sufficient of these natural soluble elements which it contains to the roots of plants, to be by them conveyed to the stem, leaves, stalks, fruit, and flowers, for their sustenance, and this will continue in almost all cases until the land is exhausted by continued cropping.*

The depth of fertility, created and maintained by continuous tillage, extends only to the depth of the ploughing or digging, and the roots of useful plants strike no deeper except in some few favoured soils. But as capillary action draws water from depths beyond that of tillage, and as such water holds in solution fertilising ingredients, which are left in the soil after sunshine has dissipated the water so drawn up, it follows that the plant often receives nutriment from depths greater than that indicated by tillage. This may account for the superior fertility of tropical and intertropical soils, which on analysis appear no richer than similar soils in more temperate regions. The evaporation of thirty inches of water in the latter, and sixty inches in the former, may account for the different result caused from the climate of two separate countries.

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* This is on the supposition that the land is not refreshed by fertilisers, or irrigation water.

When agricultural industry draws too rapidly on the soil for its products, the land becomes exhausted, or loses a portion of its fertility. It is then allowed to lie fallow, or, in other words, longer time is allowed for some of the sustentatious matters required by the plant to be separated from the soil; but it would appear to be an accompanying necessity that the soil should during this fallow be well opened, to allow the air to act in expediting the separation of the elements required for vegetation from an insoluble to a soluble state.

But since crops are carried rapidly from the land, when it is in a state of high cultivation, restoratives are required to replace fallow, otherwise complete exhaustion and inertness would ensue. Materials used for the restoration are manures, composed of organic and inorganic matter, in a proportionate amount to that which the previous crops have abstracted from the soil.

A valuable crop cannot be obtained from land except at the expense of some of the fertilising constituents contained in the soil, and it may with safety be assumed that the land will be exhausted exactly in proportion as the merchantable value of the crop is increased. But some soils have contained in their combinations a larger store of fertilising ingredients, and which they more readily part with, whilst other lands are naturally more poor and inert; but as a general rule the abstraction of value in the shape of crop will, without the application of manure, deteriorate the land, and render it ultimately sterile.* This is the case in the cotton regions of America to a very great extent; the continued cultivation of that plant on the same land has rendered the seaboard states extremely unfertile, and caused an abandónment of land, to an extent which in Europe can scarcely be realised. It is true that in some districts of the older states the permanent fertility has been maintained by the application of manures, especially that of salt marsh mud; but as a rule it has been preferred to let the manure of the plantation go to waste, and when the land has become completely sterile, then to move west; and this necessity of seeking fresh land has now reached an extent which covers a considerable extent of prairie and other cotton lands of Alabama, Mississippi, and Arkansas.

It is true there is in these states an unlimited extent of untouched land, but which land requires in many parts to be embanked by levees, to be drained, broken up, and reclaimed. How far the wearing out of the land may diminish the amount of the cotton production of these countries there is no present purpose of inquiring. The subject has only now been introduced to show that even in the cotton states of America land has its limits of fertility, and the crop is not raised without the application of capital applied to cultivation, and that the natural fertility of the soil of each plantation is limited to a few years of usefulness, unless its productive power is recruited by manure.

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* Sea-mud land and nitrogeneous soil, like Tchornoi Zem of Russia, and the periodically flooded alluvial plains and deltas of the tropics, are exceptions.

But as cotton and other crops can only be raised in India and in some other countries by irrigation, it is needful to draw attention to the capabilities which waters, derived for this purpose from rivers, possess of maintaining, by the fixed constituents and the organic and other matter combined or held in mechanical suspension, the constant fertility of the land.

The fixed constituents of many rivers consist of—

Sulphate of potash
Sulphate of soda
Chloride of sodium
Chloride of potassium
Chloride of magnesium
Carbonate of magnesium
Chloride of calcium
Carbonate of lime
Sulphate of lime
Silica
Phosphoric acid
Organic matter

In these substances we recognise the ingredients by which plants enrich their sap to form their tissues, seeds, and fruit, and if products like the stems, seeds, and wool of cotton are analysed, their organic and inorganic constituents will be found to consist of—

Water
Organic matter
Ash or mineral matter

which ash is composed of—

Potash
Soda
Lime
Magnesia
Peroxide of iron
Silica acid
Phosphoric acid
Chloride
Carbonic acid

It will hence be seen that water required for cultivation, and derived either from springs rising from alluvial formations, or from rivers which have arisen from and traversed a large extent of territory, do contain the requisite nutriment for supporting vegetation in its most perfect state of productiveness, especially in those countries where evaporation is excessive, because by evaporation the fertilising ingredients are left not only in quantity, but in their most perfect state for the use of plants. To so great an extent do the fertilising effect of river-water during their overflow extend, that it is not an uncommon circumstance for a flood in the Lower Mississippi to increase the product of such land as had been inundated to sixteen bales of cotton to each hand employed.*

The waters of the lower levels of the inter-tropical rivers carry with them a more than usual amount of the constituents required for the growth of all useful crops. Besides, these waters sustain in constant activity a vast amount of insect life, even when the aspect of those rivers are not turbid. The organic and inorganic matter in life and in combination with the water will exceed twenty or thirty grains per gallon. This would restore to the soil, by the act of irrigation, if the water is copiously used, more of the essential constituents for maintaining fertility than the heaviest crops will remove. From this fact it will be seen how much more valuable to the soil irrigation will be than water immediately derived from rainfall.

The agricultural lands in the tropics contain a noticeable amount of nitrogenous material, which is in some places seen to effloresce on the surface of the ground, but existing more frequently in combination with the saline constituents of the soil. We are led to believe that this production of nitre on the land is either produced by the decay of animalcules in that portion of the water which has been spread over the land by the periodic overflow of rivers, or is formed by the co-operation of the air acting on a porous and calcarious soil during periods of long continued drought with the co-operation of the extreme effects produced by solar heat; but, whatever the cause may be, the lands are extremely rich, and scarcely diminish in agricultural value by a long course of cropping, so that manuring in most of these countries, except by irrigation, is scarcely known or required.

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* In the American cotton districts all estimates regarding cotton culture are made by reference to the number of slaves employed, as thus:—The usual quantity of cotton produced in the Mississippi bottoms is from five to ten bales the hand, though on some favoured stretches of country, by severely tasking the men, and great exhaustion of land, ten or twelve bales to the hand are raised. This, however, does not represent the real state of things, for if the quantity of cotton grown is divided by the existing number of slaves belonging to cotton culture, the product would be only one bale and a half of cotton per slave.

Sometimes tropical soils are so saline from efflorescence that crops will not grow; but by irrigation, combined with drainage, the fertile activity of such soils may be restored.

Tap-root plants, like the cotton-shrub, strike for sustenance and moisture to the extreme limit of agricultural depth; hence the great value which will arise from deep tillage, because plants will thereby produce both stem, branch, and fruit, in size and value commensurate with the extent of root; and it cannot be too often insisted upon that one of the chief means by which a maximum crop may be obtained, is that of deep cultivation; for it must be kept in view that tillage soils are chiefly composed of the disintegrated materials of other and earlier formations, yet the ultimate division of particles composing the soil not being yet arrived at, it is no doubt designed by Nature that the separations from the earth of those constituents required for maintaining vegetable life, should be slow, limited, and proportioned only to the requirements of each succeeding generation of plant, so that the soil should not be too soon exhausted before the time for cultivation has arrived, or that the percolation of rainfall water should not too readily abstract its fertility; but when the physical operations of air and water are combined in their action by the processes required for the agricultural disturbance of the soil, the chemical disintegration is then more rapid, and the solubility of the constituents of the soil is thereby increased.

Plants will not by the direct action of that absorbing power which exists in their roots, take up either undissolved manure or those separate constituents afforded by the soil, until, by the assimilation with air and water, such solutions of food are prepared as each particular species alone requires: the spongiolls of the roots always act as filters to give time for this assimilation, and as regulators to restrain the absorption (if in too gross a state) of the ingredients required to produce vegetable expansion.

I have drawn attention to the facts and conditions connected with cultivation above narrated, because I have observed that—especially in India and Egypt and some other tropical and semi-tropical countries—there is a total disregard of the effects produced by subtillage. It is true that some soils are so porous, light, and open, that the necessity of applying all the observances connected with deep cultivation do not so extensively apply: such light soil would to a certain extent be an exception; nevertheless, the advantages of deep tillage for cotton, sugar, flax, hemp, and other valuable products, applies as a general and almost an undeviating rule, and it may be assumed that with good tillage, and the application of an adequate quantity of water by the process of irrigation, fertility will be permanently maintained.

Perhaps there are few subjects on which opinions are more widely divided than that which relates to the extent of benefit derivable from irrigation; for, on the one hand, it is assumed by those whose conclusions we are bound to respect, that even the ordinary sewer-water derived from towns underlaid with systems of drainage and supplied with adequate pipage water, is poor and powerless in the production of agricultural crops; whilst, on the other hand, examples are put prominently forward which show that by irrigation great results are effected, and lands which, from their poor and sandy nature, have by the application of town sewage attained the extreme of fertility, together with a value far exceeding that of any cultivated land known.

Now, I take upon myself the responsibility of stating that both these views of the question are quite correct, for I know of frequent cases where both town-sewage and river-water irrigations have been attempted and have signally failed; and I also am familiarly acquainted with works which have been in operation in some cases for long periods of time, where results have been attained and profits made which could neither be thought of or expected from similar, but unirrigated, soils. I am alluding to examples now in operation in various parts of central Europe.

The cause of failure, as well as the means by which success has been achieved, require investigation, so that confidence in the results derivable from irrigation may be established.

For perfect understanding of the subject it requires to be divided into three parts.

First, As to the quantity of water to be used and its fertilising properties.

Second, As to the texture of land and its capabilities of receiving water into its pores to some considerable extent.

And third, The action of water and soil after it is absorbed.

Water derived from springs containing metallic solutions, or flow from bogs, heathy moors, or containing an undue quantity of one or more organic or inorganic element or elements, are entirely unfitted for irrigating purposes; but water containing a large quantity of inorganic salts in due proportions, and, still better, some organic elements (especially nitrogenous combinations), is fitted for irrigation, provided the fixed elements are in sufficient quantity to effect the water to the extent of causing it to be hard, or what is termed extremely hard.

The waters of large rivers which have in their course descended from high and distant mountain regions and traversed great districts of country, have generally upwards of two hundred grains of fertilising material in each cubic foot, in a soluble state, ready for the immediate use of vegetation. The waters derivable from springs flowing from recently-deposited soils, as well as the waters extracted from wells situated in great diluvial districts, are generally of the same character, and are fitted also for irrigation purposes. At the part where the down-flow of a river is interrupted by (but not contaminated with salt) meeting the tidal wave, it becomes especially rich in the ingredients of fertility, and it need not be said that the sewage-water of towns contains all the elements required for every description of vegetation, but the agricultural value of which is limited in proportion to the amount of water with which it is diluted. The quantity of fertilising material which, if it amount only to two hundred grains in weight to each cubic foot of water (large tropical rivers are much richer), would, supposing fifty per cent. only of value was extracted from the water, leave upwards of one and a half tons of those inorganic fixed elements essentially requisite to form a crop, that is supposing three thousand five hundred tons of water are passed through the soil of each acre in one season; but as a four-course system of agricultural cropping only requires an average of about four hundred pounds of soluble inorganic elements to replace the amount taken from the soil by heavy cropping, it will be seen that copious irrigation water diffused through the soil, and supposing the water sinks to a considerable depth, it leaves behind more than sufficient for years of heavy cropping to exhaust the land. In the case of European cultivation, if sewage-water or irrigating-water derived from the tranquil parts of rivers (where the river-flow meets the tidal-wave) be used, then much richer irrigating water will be obtained than that alluded to before, consequently less water under those circumstances is required to effect the purpose of maintaining fertility.

Tropical rivers, in their extended course, become also charged with inorganic elements, alike indispensable to the growth of plants; and as irrigating water descends through the pores of the soil, they leave behind both the organic and inorganic matters, as well as the gasses with which the waters have been charged, and which are in the most prepared state to take part in the economy of vegetative advancement.

But if the unused parts of a cotton crop, consisting of stems and seeds, are returned to the soil, as has been recommended, then the nutriment contained in the irrigating water will be more than that part of the crop which is exported will ever demand for its production. Hence it may be inferred that after the land is fully fertilised by the quantity which has been saturated through it, the water will afterwards pass off without diminishing the value of the elements which it holds in solution.

In all lands formed by inundation, or such soils as have been deposited as mud, there is in a greater or less degree a considerable store of soluble organic and inorganic materials in a state fully prepared to actively enter into the operations of vegetable development; in some countries where reclamations have enclosed the saline muds contiguous to the sea an exhaustion of forty years has not weakened the force of vegetative productiveness: on soils like these, operations of irrigation will, as far as imparting fertility to the soil, be useless; the hydraulic operation in such cases will alone be limited to the supply of water for maintaining the moist state of the soil, and thereby counteracting the effect of excessive evaporation.

It is manifest that river water of a less rich character than that before alluded to will furnish material for maintaining the constant fertility of a soil, provided the water passes through and incorporates with every particle of earth which lies in depth a little beyond the roots of the growing plants.

In the various systems of culture where irrigation is used, the largest portion of the water passes over the surface of the ground, the rest sinks in; it is the last quantity which effects the most benefit; hence irrigation meadows situated in temperate regions are always most productive where the soil is absorbent, and where the most effectual means have been resorted to for drawing through the soil the largest portion of the water by drainage.

To effect complete fertility, of course a large amount of water must pass down and through the soil and not over it, or an equivalent amount of moisture of the same chemical character must be drawn up through the soil by capillarity, to be there dissipated by evaporation; from two to five thousand tons of water are required to effect irrigation in various hot and dry countries, the diminution from the larger amount being caused by occasional rainfalls, and of the larger amount is demanded in consequence of the absence of all moisture derivable from atmospheric supply, except that of occasional and unfrequent rainfall, and the constant deposition of moisture from dew. Taking the minimum amount of irrigating water above stated as capable of affording the nutriment for plants through one season of cultivation, and supposing fifty per cent., not absorbed, five hundred pounds of inorganic dissolved constituents would be distributed through every part of the soil, besides the organic elements which would be taken up by the soil without diminution.

It must be noticed that the available inorganic material alluded to is that which is held in solution ready for immediate use; but an analysis of soils often shows a soluble amount already existing in the soil, extending to five or six hundred tons of constituents; but this, it must be observed, is a quantity only dissolvable by powerful acids, and would only be available after ages of unlimited extent. To understand this part of the question more perfectly, it may be well to state that the only part of a soil available for the requirements of immediate demand is that which may be separated by soft water; such solutions are called active ingredients.

That material inherent in the soil which, only dissolvable by soft water and by the lapse of long periods equivalent to geological epochs of time (the extent of which cannot be either estimated or surmised), is called the passive ingredient; and that part which does not dissolve by acid, but gives the mechanical and structural faculty to the soil by causing it to be porous, and thereby available for the entrance of water, air, and the spread of the roots of plants, is in no other respect capable of promoting vegetative increase; it is therefore called the inert portion, and when the soil is good, there is seventy or eighty per cent. of this material in the entire quantity.

The waters of rivers in such seasons as when their volume and consequently their velocity is increased, contain a considerable amount of undissolved earthy matter in mechanical combination, which when tranquilly deposited forms mud; this material is entirely in excess and distinct from the chemical solutions of inorganic salts with which the water is also combined, and which have been referred to as available for immediate use in promoting vegetable fertility. This material held in mechanical suspension and capable of readily forming mud is sometimes called warp; it is composed of infinitely small and almost invisible particles; the soils accumulated from these deposits vary in the coarseness of the atoms in a proportion corresponding with the velocity of the streams by which they have been transported; two hundred grains and upwards to one cubic foot of water will be the amount which an ordinary river will bring down during floods, but tropical rivers, when their velocity is increased by being gorged with water, bring down much more. This fine comminuted material held in mechanical suspension, is often used for creating a soil over peaty bogs, when the levels of the river and the moss admit of such a proceeding.

The soil thus formed is of first-rate character for vegetable productiveness, because the extreme division of the particles facilitates the operation by which rain water sinks in the soil and extracts nutriment from such organic and inorganic element as the soil furnishes by disintegration and solution: good warp soils require no manuring for several years; but constant and incessant cropping demands at last that either fresh warp or artificial fertilisers be resorted to.

I have mentioned these facts because there is often an impression existing that extreme fertility is derivable from the mud flowing down rivers, but such is not the case, except to the extent I have indicated; besides the deposit of rivers do not contain equal degrees of fertilising ingredients, sometimes so much silex exists that the mud may be termed poor, the organic and inorganic matter held in solution are the only valuable and readily available fertilising material for irrigation purposes which rivers can supply; it is requisite, however, to make exception in favour of quietly deposited estuary mud, composing in part or entirely sea shore land, raised above ordinary sea level by succeeding spring-tide deposits. The sea is so full of fertilising ingredients brought in part from the land by the great rivers, that these muds if transferred to exhausted soils in considerable quantity become manures. Irrigating wells, sunk into the gravels and sands of alluvial and diluvial plains, generally afford water which has been so long in contact with the subsoils that their supply often contains amounts of fertilising ingredients, equal to that found in rivers in which case the water is hard, clear and transparent; nevertheless the fertilising character is often equivalent in amount, and sometimes exceeds that of rivers, we may refer for example to the innumerable irrigating wells of Lombardy.

Having so far treated the subject of the application of water to land, not only for communicating moisture to the soil, but as showing the fertilising properties of such water, attention must also be directed to the second branch of this question, viz. the mechanical texture of land, and its capability of receiving water into its pores in considerable quantities, and to a given depth; soils are porous or non-porous according to their composition, and receive water in proportion as the inert particles of which they are chiefly composed are capable of maintaining uniform porosity; that is to say, if the alumina and silica and other plastic materials forming another portion of the same soil do not entirely fill the spaces between the particles of the sand. Openings in infinite numbers exist, in each cubic inch of soil through which water permeates in its descent, and is drawn through by the force of capillarity in its ascent to, in part only, fill the void caused by evaporation.

A soil so constituted, supposing it does not chemically contain any inorganic element in a redundant quantity sufficient to interrupt the due progress of vegetable growth, is the proper soil to irrigate. Water passing through such a soil, by the mediation of its alumina, silica, and lime, extracts the greatest portion of the soluble elements the irrigating water contains. The water can be filtered through a soil of this character without difficulty, so as to render it sufficiently fertile to grow the heaviest crop, providing the irrigating water contains from one hundred and fifty to two hundred grains of dissolved elements in the requisite proportions.*

Should the water possess a higher irrigating value, then a more open and less fertile soil would give an adequate return, but if the sewage of a town is required to be distributed over land, in that case the soil should be of a more sandy character, and in European tillage the best results are obtainable from the cultivation of grasses on such soils, because the sandy-barren roots send out their fibrous spongioles in the soil to a considerable depth, and in every direction, and by the decay of the useless roots of the grasses, the ground soon becomes supplied with the Humic and Ulmic acids, which arrest and combine with fertilising materials contained in the irrigating water. To such an extent is this the case, that strong sewage water may be spread over a silicious sandy-barren soil, and yet produce good crops as with result, may be seen near Edinburgh, but even here by the concentration of the process of irrigation on too narrow an area, by the employment of water too strongly charged with fertilising material, and by drenching the ground with too large a flood running merely over the surface at the irrigation period, the results are much inferior to that which the ingredients are capable of giving in vegetable produce if a more correct system were adopted.

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* It is important to keep in mind that the moisture drawn up by the capillarity only occupies a portion of the interstitial part of the soil, the other part being filled with air.

It is useless to irrigate close impervious land, especially clay, or even gravel or sandy soils, when the latter has in its composition aluminous sticky clay, interposed between the particles of sand and gravel. It is true that in some portions of Egypt and other hot and dry countries clay may be irrigated, but then the soils shrink, and crack in all directions on the surface being desiccated by the heat of the sun, though a little lower in the ground it may be still moist, and as plants, such as wheat and cotton growing in these soils, strike well down by the roots, a considerable interval of time may be allowed to elapse before the water need be again applied, and when it is the small superficial cracks admit it readily to a depth of three or four feet.

The third division of the subject relates to the fertilising co-operative action of air, soil, and water, after the latter is absorbed.*

Water, after being spread over ground requiring to be refreshed by moisture, will gradually sink therein, and will displace the air which occupied the interstitial spaces; therefore if the water is absorbed, leaving only moisture and nurture behind to the level of the cultivation, and which may be assumed at one foot six inches to two feet six inches in depth, the new volume of air following the water would, in the first case, occupy a space in the tilled soil equal to eleven, and in the latter case, to eighteen thousand cubic feet of air per acre, expelled and again drawn in by the activity of the irrigating operation. The amount of air thus absorbed by the pores of the soil, in addition to that space occupied by the water retained by molecular combination, is a cause of respiration of air by the soil, produced by the act of absorption, and creates one of the most important agencies whereby the dormant faculties of the soil is brought into full activity, because we must always keep in mind that both air and water are allied and combined, to a limited extent, with gases of a character especially available for vegetative progress; and as the soluble alumina and silica in the soil are the recipients of these gases, and, still further, as integration of the quiescent parts of the soil can only progress by the co-operative action of these elements, it may be concluded that the maintenance of these agencies in the continued activity of their functions is not alone important, but indispensable to perfect tillage. No doubt nature performs the same operation by showers, by dew, by radiation, and by dilation of the air caused by the difference of the temperature of night and day, and by evaporation when the soil admits of the superfluous rain-water sinking below the tillage depth; yet as land is often surcharged with water, too much exhausted by the extraction of tillage crops, or is situated in countries where continued periods of dry weather suspend the progress of tillage and the growth of vegetation, it is in such cases that husbandry invokes the aid of science and art, but so far only as may assist nature to pursue her undeviating course of perpetual activity.

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* Shrinkage of the soil in these hot and dry countries sometimes equals fifteen per cent; in the very dry seasons I have measured shrinkage spaces greater than this; the crack openings were too great for horses to travel safely on account of their feet being liable to get into the innumerable cavities.

If all the subjects just stated are fully examined, it will become apparent that the process of irrigation may be ineffectual, unless all the conditions of the soil and the qualities of the water used are not in accordance with the chemical requirements necessary to maintain soils not only in a state of fertility but also mechanically qualified by porosity to administer that fertility to the growing vegetation; but if the physical, chemical, and mechanical conditions harmonise in their action, then the irrigation process will not only be successful but extremely profitable. For the purpose of elucidation, the observations which I have recently made relative to irrigation being sometimes successful and sometimes a failure, I have referred more especially to European experience of the results derived from the process; but in respect to tropical irrigation no doubt can arise as to the commercial advantages which must follow its use, and which may always be measured by the perfection of the system adopted.*

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* I consider that maintaining the water in canals and cuts at a proper level, to be one of the systems of irrigation.

Some few matters still require explanation, because of their important bearing on the action of air and water in combination with cultivable soil, and have especial reference to the effects produced by irrigation. The quantity of water held in combination with the soil to form adequate moisture for the support of vegetation, from the surface to two feet six inches in depth and one square acre in extent, is about two hundred and fifty tons in weight.

That portion of water which rises to the surface by capillarity may be evaporated in the dry seasons of the tropics in about seven days. If the evaporation was direct it would cause a consumption by evaporation amounting perhaps to upwards of three thousand tons in the course of the dry season, supposing no casual rain fell in that period and that the thermometer stood at a mean temperature of about eighty degrees; also supposing the surface soil frequently in the mid-day sun uncovered by vegetation on the upper surface, and to one or two inches in depth has attained a heat of one hundred and twenty degrees. These facts would seem to indicate that for irrigation purposes any amount of water would scarcely be sufficient to meet the requirements of excessive evaporation, which often reaches from one quarter to half an inch per day.

On the other side of the question there are circumstances which countervail the excessive dissipation of water by solar heat. Water occupying the spaces in the soil as moisture can only be dissipated by rising to the surface by capillarity, which will maintain its activity only in proportion as the moisture is dissipated from the ground, but as the vapour required to supply that waste is only formed below the ground after solar heat has for some time acted upon it, the vaporisation will extend only two or three inches below the earth's surface, and as the heat to form vapour can be obtained alone by abstracting it from surrounding bodies, a diminution to an extent of ten degrees below the mean temperature will ensue. Whilst the crop is growing the same effect to a less extent will take place by the dissipation of moisture from the leaves of the growing crop, in addition to which during night, when the thermometer has fallen fifteen or twenty degrees, the ground will then, after a continuation of great heat and near the sea, re-absorb moisture weighing from thirty to forty tons to the acre; hence it will be perceived that the quantity dispersed by evaporation from the surfaces of water will not correctly represent the quantity dissipated from the ground during a dry season; it is therefore clear that in all cases each change in the texture of soil, the comparative alterations occurring in climate by reasons of contiguity to oceanic currents, or by elevation of country, together with investigations relative to the amonnt of rainfall, deposition by dew, the nature and temperature of soils, the qualities of river and subterranean water, must all have due and separate consideration not only in estimating the amount of water required for irrigating each acre, but also in maintaining its constant fertility when heavy crops are drawn from it by improved cultivation.

CHAPTER XIII.

ON STEAM AND ANIMAL PLOUGHING.

To break up and perfectly cultivate wide stretches of level alluvial land it appears obvious that steam-ploughing, that is to say, the plough, or rather a series of ploughs, actuated by a portable steam-engine, in combination with machines and implements, is in every way adapted to the full and perfect accomplishment of this object. First, the steam-plough will strike deep in the ground for effecting the first ploughing, and let the air into soil never before exposed to the full effect of atmospheric influence. Second, a large area of land will be brought into cultivation in a very short period of time, a great amount of manual labour and all animal assistance will be dispensed with. And, thirdly, the tillage will not only be more perfect than any ever yet practised in tropical culture, but at the same time it will most materially reduce the cost, whilst the results will be rendered more certain, because of the greater depth to which the pulverisation of the earth will be carried.

As alluvial or diluvial plains, such as have often been referred to in this report, afford the greatest possible scope for the perfect and uninterrupted movement of the steam-plough, whether actuated by a portable engine moving forward by successive gradations on the land, or from an engine placed in a floating vessel on a canal, as referred to before, it will always be found consistent with simplicity and convenience to work the engines co-operatively in pairs, so that the tail of the plough always draws a rope from one engine whilst it is being drawn by the other; and for the working of this system two sets of ploughs and two sets of winding-drums must be used, with proper clutches for disengaging the run-out of the wire rope; the ploughs will pass each other in the middle of the length of the furrow, and will be about eight feet apart, the winding-drums will be placed on the end of a shaft running along the whole length of the engine, and which shaft will be driven by gear having arrangements for reversing the direction of the revolution of the drums. This system of working will be found simple, and will dispense with a great length of the hauling line, which is now indispensable when only one engine is used. By this mode of tillage stretches of country of many miles in length, and of a width of four hundred yards, may be ploughed as a single field; and as alluvial plains are always level, and as no obstructions to the plough ever occur, at least from two to four acres per day* may by each pair of ploughs be completely tilled and made ready for seed.†

So far reference has been made only to the first deep ploughing by large single shares, but for the usual, more superficial, and subsequent routine of cultivation several furrows, or slices, will be turned over at once by each plough; and for cleaning cotton ground, if steam power is used, it will be only needful to put the hauling-lines over the rows of trees, and then dropping them in the alleys, and the two sets of ploughs will each clean and harrow the whole breadth of an alley at one bout.

Instead of at all times using the system of steam cultivation I have just described a less costly process may be adopted for cotton tillage. It is well known that trees and shrubs, even when the branches are interlaced at the top, do not by their roots occupy all the ground upon which they stand, therefore it has been thought desirable to devise a means of steam cultivation which will easily till the ground for the first year's crop to a depth of three feet. This process will cut the soil in all directions into cubes of a size not larger than one inch on each side, and will leave the ground so light and open that the roots and rootlets of the cotton-tree may expand in every direction, but at the same time limiting the tillage area to a width only actually occupied by the plant underground.

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* Since the above was written, I have had some communications with Messrs. Ransome, Sims, and Co., respecting steam-ploughing, and I find from them that the double systems of ploughing by two separate and co-operative engines has for some time been in use by Mr. Fowler, an engineer, who has done so much to bring the system of steam cultivation into extensive use.

† This refers to deep ploughing.

Of course, at the second season of planting the unoccupied and unbroken subsoil forming the alleys will be tilled, and on which the rows of the new crop will be planted; but if the trees are allowed to remain as perennials, then at the second year the spaces forming the alleys will be cultivated so as to let the roots further expand in fresh ground.

As the soils will, as before indicated, require various methods of treatment as regards the system to be pursued for supplying water to or draining it from the cultivations, and as that supply will, when practicable, be obtained by the conduction of canals, and as a considerable portion of the cost of bringing the land into perfect cultivation is caused by the expense of canals, it becomes a question of great interest to see how far the operation of ploughing by steam will facilitate the construction of these conduits. Now, as the principal, and in a tropical climate the most grievous, part of the labour is comprised in digging the ground, for either sinking the canals or forming the banks, or, as is often the case, these two operations are combined, it is clear that, so far as excavation is concerned, the steam-plough could at once abridge labour in this respect to a very great extent, by cutting the ground into furrows along the length of the canal, and of a width and depth to be fit to form blocks of earth of a size easy to handle; and in forming the blocks they could with care, by ploughing, be made to form masses nearly as solid as the ground was before separation. These ploughings could be performed in horizontal sections, each section being narrowed to the regular slopes which form the sides of the canal as they sink lower; and as the sections would be about one foot in depth a canal of four feet, or a side-cutting of similar depth, would require four ploughings only to effect the excavation. This would reduce the cost of taking out the excavation after ploughing to one penny per cube yard, even supposing the native population of India or Egypt received as much as sixpence per day (which is in excess of the present price of labour in either of those countries); and as the cost of ploughing the ground into slices of one foot sections will not reach two farthings per yard cube, moving the excavations and forming the banks by the co-operation of steam power will not be more than ten farthings per cube yard; this, with the addition of other details, will make the cost of a canal of a mean width of sixty feet and six feet deep, formed by three feet of excavation and five feet of embankment, with contingencies and sundries, amount to 350*l.* per mile; but the work contemplated would be perfectly finished, with two puddle dykes run along each bank and grafted into the seat. One slope of such an embankment would form a raised road, and both the slopes would be dressed to a uniform lay, with a proper soak-drain in the rear.

I am aware that canals have been made both in India and in Egypt at a rate even lower than this amount, but with labour at each of those places at less than fourpence per day, and the works in Egypt have been of a much ruder and less efficient character than those on which the above estimate is formed. Canals raised entirely above the ground will cost in their construction a larger amount than that above stated, because in that case the full quantities of earth required for the embankment will have to be taken from a parallel side-cutting; but this side-cutting will always serve for an exhausting drain for freeing the neighbouring land from superfluous water.

A further diminution of the cost of canal construction will be found in the employment of a machine, driven by a portable steam-engine, for hauling the ploughed sods from the bottom of the cutting and depositing them on the embankments, thus reducing the manual labour to that of filling the sods into the movable compartments of the machine, dressing the slopes and puddling where necessary.

Previous to concluding this part of the subject, it may be as well to state that before the rate of fall of a canal is decided upon, it will be requisite to take into account the probability of such canal being required for navigation purposes, in which case the fall may be somewhat less per mile than would otherwise be adopted; this will diminish the volume of water flowing through the canal, but although the navigation be improved by the diminished fall, yet the size of the canal will require in a corresponding degree to be enlarged, by which means the expense will be increased, but not in a proportion equivalent to the amount of benefit which will be derived from the introduction of so useful a work, even though it is limited only to local purposes, because all these canals must of necessity proceed from and be connected with still more extensive navigation, and ultimately with the great rivers, by which means the internal intercourse of the country will be greatly enlarged.

The names of the parts of such ploughs as are best adapted for Indian cultivation, are as follows:

The frame is the centre portion to which the numerous parts of the plough are affixed.

The beam is a bar of iron, or wood, fastened to the top of the frame; the draught is from the end of it.

The stilts, or handles, as the name implies, are the handles used to guide the implement; they are called the great and little stilts, the inner one is fixed in line with the beam, the outer one is set at an angle with it.

The mould-board, or turn-rest, is the curved part fixed to the plough-frame, which gives the necessary twist to the seam of earth when cut by the coulter and share, and causes it to lie over into the seam previously cut.

The sock, or share, is a continuation of the mould-board, pointed at its outer end and sharp in front; it cuts the earth horizontally at a given depth, and raises it a little, leaving the mould-board to eventually turn it over. The coulter is a knife fixed vertically into the beam, sharp on its front edge, and thick and straight on the back; it is set at an angle to the beam, varying according to the sort of work; it cuts the earth vertically, as the share cuts it horizontally, and the mould-board lays it in its place.

The slade, or sole, is a flat iron plate fixed horizontally to the plough-frame at the bottom of it; it runs on the lower part of the furrow previously cut by the share.

The hake is an apparatus fixed at the end of the beam to which the horses are fastened; it is so constructed that the draught may be adjusted to suit any number of horses or change according to the character of the work required.

The wheels are of various kinds; to carry the weight of the plough or steady the beam a large wheel runs in the furrow, and a little one on the land. Wheel ploughs are of great variety.

The cultural effects produced by ploughs working by animal draught may be considered as a substitute for digging, whether done by the spade or spud. In digging, the earth is cut and brought to the surface, turned right over, and is thrown down with a jerk, by which it is disengaged, leaving considerable interstices, so that fresh particles are exposed to the atmosphere; the fork or spud effects this purpose better than the spade, consequently the latter is used by tillage gardeners in preference, the ground being more thoroughly broken up, loosened, and exposed to the sun. The plough, although used as a substitute for the spade, does not in clay soils effect the same amount of good, because the plough cuts off and merely lifts up a long slice of earth, turns it over, and leaves it resting on a slice previously cut; only the side and surface is thus exposed to the atmosphere, and if the land be at all sticky, the side and bottom of the seam of earth cut is polished smooth by the pressure of the mould-board in turning it over. Only a minimum amount of benefit is derived by ploughing the land very smoothly as compared with digging, because scarcely any of the slices get broken, consequently the particles of the earth do not get the adequate benefit from the effect of the air, by its acting on the soil. The land is generally laid up in rounded ridges, with furrows between, for the purpose of securing in clay soils efficient drainage, if the ploughing be well done; after all the seams have been turned over the surface of the ridges under the ploughed earth will be smooth and even, and the water will flow easily away to the furrow; if it be badly done, there will be notches and projecting pieces which will prevent the water running off, and bad places in the crop will be the consequence. During the ploughing, the sole of the plough presses on the bottom of the furrow with great force, making it hard and smooth; this is a great defect, as precisely the reverse should be produced, or the roots of the plant cannot penetrate below the few inches of earth that the plough has disturbed; a light subsoil plough must, therefore, be continually used after the plough, that is, every second or third year, or else the crops cannot be other than small. A small wheel is sometimes fixed to the plough-beam, to run on the land and support it, so as to decrease the friction of the sole and keep it more even on the bottom of the furrow.

For ploughing between cotton rows and for seeding the ground many modifications of the mode of operation may be made, varying as the texture of the ground changes, from stiff clay to light sandy soil, and although the shape of the plough may be variously modified, the name and use of the parts will be much the same. The principal change will be chiefly confined to the slade, mould-board, share and cutter; these will be all modified in shape, and sometimes the mould-board will be dispensed with, and either the American bull's tongue, or a large duck's-foot cultivator may be substituted; all these implements and their modifications, together with the scarifiers and plough-tail harrows (for tearing out weeds whilst the plough is operating below in lightening the ground to let in air), will constitute the stock of implements for working the ground for cotton culture, or for raising other vegetable productions when the crop is grown in rows.

After the well-formed two-horse Ipswich light plough, the most useful implement which could be introduced in tropical cultivation would be a small short-handled, single-shared, steel-pointed, duck's-foot plough, but which may be termed a cultivator; the sole should be so broad as to cut upwards of twelve inches wide, and be efficient to sever weeds about three or four inches below the surface; and although opening the ground to a very considerable extent, this implement will not turn it over, but leave it smooth and more open. After which a horse or hand-rake should be used. To remove superficial weeds, and also those which had been cut by the cultivator, the beam of this plough should be very short, and if drawn by a light tractable mule the work will be done without disturbing cotton or other crops planted in rows.

Unless the precaution is observed of removing the weeds from the ground many would again commence growing, although the root is entirely severed, for in the tropics even the stems of many plants and weeds, if the soil is moist, will again grow by commencing formation of the new roots; therefore it is requisite that a weed scarifier should always be used after, and not before, surface irrigation; and it may be as well to observe here, the weeds should be completely dry before the water of irrigation is brought to the ground. If a small and very light short-handle plough, built with the usual mould-board, and a small tractable draught animal be employed, much good may be done in stirring the ground between the rows of trees on cotton plantations. This stirring will keep throwing the furrow slice each way towards the trees, by which means they will gradually stand on low ridges. Now if, just before the monsoons set in, a double-sliced furrow is thrown out on each side, a good drain will by that means be formed for carrying away the heavy rainfall water. This will be accomplished by a plough modified for this especial use. With the light plough and the cultivator, described above, together with well-devised weed-harrows and the use of the hoe, the work of the cotton plantation may be carried on until the branches commence to interlock; but if the cotton-plant is cultivated as an annual, the ploughing before the seed is put in may be accomplished by a steam-plough, which will completely break up and turn over the ground at least eight inches deep, and after each plough there should follow along the ground, opening it at the bottom of the centre of each furrow, a small subsoil plough, drawn by the same engine, and having a round share like that of the Kentish turn-rest plough, and called in the American plantations a bull's-tongue plough; this will open the ground to a further depth of eight inches, making a cultivated depth of sixteen inches. The operation of this cultivation is irrespective of the subsoil ploughing recommended to be always done on the commencement of the first breaking up of the soil from its native state, and continued at intervals afterwards.

CHAPTER XIV.

OBSERVATIONS RELATIVE TO SUBTERRANEAN WATER-LEVELS IN LARGE DELTAS, ALLUVIAL PLAINS, AND DOABS.

When rains fall on the porous soils of alluvial plains the water will sink into the ground to a depth which will be represented by the surface-level of the sea, a contiguous river, or some collateral stream, until the rains have ceased for some time; after which the depth of the water will begin to decrease, the absorbed water above the slope of the future water-level will begin to flow out horizontally through the gravel and sand; the surcharged line is then called the subterranean water-level.

Although we call it a water-level, it never is a true level, but a varying level, deflecting more extensively towards than from the line of discharge. Suppose, for example, the surface of the river to be always at one uniform level, and suppose also the rainfall to be equal in given intervals of time, the subterranean level would be a uniform slope towards the line of depression, which most probably would be a river. The amount of deflection towards the outlets would then represent the friction of water passing through sand and gravel; to overcome which would require a fall per mile:

	Feet per mile.
Through material like chalk . . .	30 to 50
Through sand	20 to 30
Coarse sand	15 to 20
Fine gravel with some sand	13 to 15
Coarse clean gravel (one-inch mesh)	5 to 13

The above figures will represent the underground water-level, supposing all things are circumstanced as before stated; but if the river begins to rise, or when rain falls in excess, and at some remote distance from the river, then the nature of the level will be for a time changed, and as the river rises there will be two deflected lines, one running from the river, re-surcharging the ground which was before dry, and the other flowing towards the river, meeting the new line of deflection; these lines would go on changing until all the pores of the ground are again re-surcharged with water, or the river sinks to its usual low level; of course, as before stated, the fall towards the river is more uniform than that from the river.

It is evident that the deflecting line of underground water will fall each way, as in the case of doabs, or diluvial islands, lying between divided branches of rivers, the centres of such areas will consequently be swampy during and immediately after much rain.

From what has been said relative to subterranean water contained in alluvial plains, it will be perceived that at moderate distances from rivers the line representing the water-level will rise to the surface, and prevent the rainfall sinking into the ground. For instance, let us suppose an area of land situated from four to eight miles from a river, and that the surface-level of the water in the river had been stationary for some time at thirty feet below the level of the lands composing this area, it is clear that a rise of the underground water-level of thirteen feet per mile would within the distance of from four to eight miles, bring the water-line to the surface of the ground; therefore, some of the superfluous or unabsorbed rainfall of the country lying beyond this distance must, if the country is cultivated, be carried off by surface natural drainage (the flow of water from which will often cut small erosions or nullahs), whilst the rest remains in depressions or uneven places until evaporation has not only taken off the surface-water, but has dried the ground to a depth sufficient to permit the commencement of agricultural operations; these observations serve to show that unless a natural drainage does exist, the great necessity there always is of adopting a system of drainage at even a moderate distance from rivers, for carrying off superfluous rainfall water, both on account of maintaining a heathful state of the air, which this species of swampage is liable at some seasons to subvert, as well as from the greater facility of commencing agricultural operations much earlier after the cessation of heavy rains and floods; and from the greater faculty which drainage imparts to the soil of maintaining every part of the year that state most conducive to the continued growth of plants.

The study of the peculiar characteristics of the soil in reference to its composition and openness, and also its power of transferring water through the pores, together with the general slope of the subterranean water-level, is essential to the attainment of a knowledge of the quantity and constancy of the water which may be obtained by sinking shallow wells for the supply of districts remote from rivers. It will often be found to be less costly to obtain water from a subterranean source than to resort to a river; of course, at all times the qualities of the ingredients contained in the water must always be ascertained, and the fitness for such water to promote the growth of plants be taken into strict account before any plan is adopted for an extensive work.*

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* The time consumed by inflow side penetration will always have an important bearing on the water-level deflecting from a river during floods.

CHAPTER XV.

OBSERVATIONS ON THE POWER TO BE EMPLOYED IN RAISING WATER FOR THE PURPOSE OF IRRIGATION.

THE first division of this subject relates to the hydraulic power derivable from the adoption of barrage, it being clear that all water artificially raised by this system and usefully applied to land, is equivalent to a mechanical force which must have otherwise been called into action for raising the same volume of water from the low level of a river, or from a series of wells or tanks; the barrage in its duty would be analogous to a dam for impounding the water intended to drive a water-wheel, and which water is the only vehicle by which power is transmitted to the machinery driven by the wheel, the real power being, in fact, the water raised above its natural level by the dam, and the measure of power is the amount of water let into the buckets of the wheel, minus thirty per cent. for friction and loss of force during the transmission.

Viewing the effect of barrage in this light, and its capability of raising the level of the water for the use of districts containing, let it be supposed, for example, an area of one hundred thousand acres, and that each acre demanded three thousand five hundred tons of water for irrigation, that the river by which the irrigation is effected was raised thirty feet by the barrage; and if it is further supposed that the river (on the average of the length to which the water rises) would still require an artificial lift of fifteen feet, the work of seven thousand oxen working in well-constructed mills would have to be called into action to do the same work; but as mechanism is constructed in India, in Egypt, and other Oriental countries, it would require during one hundred and fifty days in the year the force of ten thousand oxen and the labour of thirty thousand attendants each day; or if the labour of men was substituted for cattle, as it frequently is in India, it would require one hundred thousand men the same number of days to produce the same result.

It would not be judicious to raise, by the direct action of barrage, the level of a river to a height which would irrigate the land direct; this precaution has been referred to before;* the extra lift must be overcome by the application of other power, and a considerable portion of this extra power may be obtained by applying the French turbine, so as to be actuated for the purpose of pumping by a portion of the unused overfall of the barrage-water; the outfall must be diverted by side-cuts through the system of turbine cylinders placed on each side of the river. After the water has performed its duty of actuating the turbine, it must be discharged some distance below the barrage, the turbines must be attached to the machines for raising the water which is to be delivered into some of the great canals, which would, of course, have their commencement at the barrage.

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* If the river occupies the higher levels of the country, as many tropical rivers do, a side canal may be made so as to divert the water laterally until a command is obtained in the lower country

Other canals would by means of cuttings effect the necessary communications with lower lying countries, and at the same time have sufficient command to feed by natural fall particular districts; but there would still be divisions of territory situated above and at some distance from the barrage, beyond the reach of the power derivable from overfall, and which would require mechanical power to be applied for raising the water; this circumstance brings us to the consideration of the description of mechanical power best adapted to raise water at distances from overfall of the barrage, and that also derivable from wells and other detached supplies of irrigation water.

The cost of steam-power in India is very high, on account of the difficulty of obtaining fuel; but the advantage of that power for ploughing and for other purposes is so great that its employment must be admitted to a certain extent as an auxiliary to good cultivation.*

The cheapest power to be employed in India for many purposes will be that of the wind; but precautions are to be taken against the effect of the monsoons acting against the structures to be erected for obtaining this power; it is necessary that the wind-engines be built of greater strength than is considered necessary for similar erections when this description of power is placed in exposed situations in England. I am not disposed to recommend any change in the principle of the mechanism of the English windmill, except increase of size, strength, and the adoption of a structure of iron for the tower, which should be left entirely open to the lower end of the sweep, so as to allow the wind to pass through it without interruption; and further, that the sweep shaft be entirely horizontal and in a state of equilibrium on each side of the tower, and should project from it both back and front; on each projection should be placed a set of sweeps, one on each side of the tower, taking the precaution of not setting the sweeps in the same line of the wind, but alternating them so that four sweeps on each side may divide a circle into eight equal parts; of course two fantails working in unison, one on each, must be used to bring the head round to the wind.

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* If a system of river barrage is adopted in India, the resulting mechanical power would be so great that it is quite useless to speak of its ever becoming a valuable element of commerce. The quantity of power required for lifting water for irrigation is only a small fraction as compared to the total quantity of overfall which will always result from the application of barrage.

A wind-engine of this description would be equal to a steam-engine of twenty horses, but would always perform the average duty of ten-horse power; it would be sufficiently simple to be within the comprehension of, and might be worked and superintended by, a native of either India or Egypt.

Wind-engines connected with scoop-wheels are often used in Holland for lifting water out of the country and discharging it into the sea, and are placed in one to two hundred in groups, and at a small distance from each other; they have always effectively performed the duty, but the low price of coals, the convenience of landing the fuel near the engines, and the great duty performed by a given quantity of fuel, have to a considerable extent limited the further use of wind-engines in raising water in that country. Steam-engines of vast power have been used for the last twenty years in raising immense volumes of drainage water to be ejected from the land, which process is the very reverse of what is required in India, viz. the retention of great volumes of water to be spread over the surface of the country by irrigation.

Some of the steam-engines employed in Holland have cylinders of twelve feet internal diameter, working from five to eleven pumps, in groups attached to each engine; the internal diameter of the pump-barrels being seventy inches, and having twelve feet stroke.

Having been connected with these works from their first introduction, more than twenty years since, I have always seen the great advantage to be derived in India by the application of great system of irrigation, and accordingly brought the subject before the chairman of the then governing body of that country; the result may be assumed, and the amount of encouragement inscribed in a small space by a few words.

As the power of steam must hereafter be frequently called in aid of other power employed in any perfect system of tropical or intertropical cultivation, and as fuel is often scarce and dear, it is a subject of much importance to decide correctly as to the nature and principle of the steam-engine employed in India.

For the purpose of obtaining the greatest amount of available power from the smallest quantity of fuel, the steam should pass through two cylinders, steam acting in the first and smallest cylinder by pressure, expanding in the second, and condensed in the usual manner; and as all steam-engines alluded to in this report would be employed near a water supply, I recommend that even when using the small portable engine this system be carried out, and that condensation in every case be resorted to.

In France and many other parts of the Continent, where fuel forms an important item of expense in all industrial operations requiring steam-power, the system of twice using the steam took its position, and is maintained to the present time, because it is justly considered to be an economical proceeding to incur a larger expenditure in the first cost for a perfect machine, whereby the annual expenditure for fuel may be greatly diminished.

Of course the advantage derivable from the application of a judicious system of drying and superheating the steam must at all times be kept in view.

The comparative cost of fuel will stand as under:

	Per horse-power per hour.
Ordinary high-pressure . .	14 lbs.
Steam twice used	4½ lbs.*

By the introduction of the system of barrage, falls of water may be obtained for raising other volumes of water to higher levels, and for all purposes to which mechanical power can be applied. This power would be produced by water acting on turbines, and has been before described under the article relating to irrigation. This power would not be available during the seasons of flood, because at such times the caissons of the barrage would be removed, consequently there would be no overfall in the river; but for a great portion of the year a large water power would be available.

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* A deduction must be made from the above statement of advantage on account of the condensing power of water (from the high range of temperature in the tropics) being reduced.

CHAPTER XVI.

ON THE GERMINATION OF SEEDS AND THE GROWTH OF COTTON-TREES

A SEED consists of three parts; the germ of the future plant, the food for supporting the germ, and the envelope for clothing and protecting both embryo and sustenance.

The germination is performed in this way: the germ, however small, consists of two parts, the plumule or minute vegetable point, some part of which appears on the surface of the seed and is destined to form the future stem (its inclination being to seek light and ascend upwards); and the radicle which forms the future root, having from its development to its maturity the inclination to avoid light and to descend downwards into the earth.

Agricultural seed, unless supplied with adequate air and moisture, cannot germinate; but if the quantity of water be too large it will make the effort to grow, but its vitality will immediately expire; it is only when moisture gradually assimilates by gradually dissolving the gluten and albumen required to form the diastase or food necessary for the development of both radicle and plumule, that the indications of vitality begin to assume a tangible form.

The nutriment required for the germination of the plant is in the progress of this preliminary stage derived alone from the seed until it is exhausted; the roots then begin to search the soil for food to continue that vegetable growth which the seed has commenced. Seed germinates by the joint action of heat, moisture, and air, but until the rootlets are formed and capable of drawing up from the soil moist assimilated food, and until the nutriment existing in the seed is entirely exhausted, light is not required; but when the gemmule or future stem of the plant is developed, then embryo leaves begin to expand, and by the cooperation of light to decompose carbonic acid, and to appropriate the carbon in enlarging and hardening the tissues.

Seed is put under ground for a threefold purpose: first to exclude light, next to retain moisture by means of an envelope of earth placed over it, and lastly to interpose a medium between the sun's rays and the seed; this medium is the upper soil, which at two inches deep will arrest and retain moisture in its capillary progress to the surface of the ground required to re-supply the water dispersed by solar evaporation.

If seed is put too deep into the ground it will not grow, because the penetrative power of solar heat is diminished, although largely required in the first process of germination, nor is the tender plumule which precedes the stem endowed with sufficient strength in but few plants to open the way to light; from this fact, the importance of drilling seed into the land will at once be perceived as compared with the broadcast system, as well as by the favourable result derived from machine over hand-dibbling.

A developed plant like the cotton-shrub or tree is succulent and cellular during the early period of the formation of the stem and until after the first three or four leaves are spread out; the centre stalk then becomes more ligneous and dense, the process of forming wood extends and lateral branches grow out, until the ground is shaded over by the interlacing vegetation; from the lower part of the neck from which the stem springs upwards the root strikes down in a direct line, forming the tap or central root, from which all lateral roots spread out; the cellular tissues which cover the extremities of the roots are the spongioles, by means of which the fluid nutriment is conducted to the stem, branch, and leaf. A close examination of the delicate filamentaceous substances which form the extreme of the root, will indicate the necessity which exists of tilling the ground deep and wide, and breaking it up into small particles to let the tissues spread in every direction, because in their growth they are always radiating from their common centre;

the same examination also shows that to charge the ground with too much moisture excludes the air from acting with the spongioles in assimilating, preparing, and afterwards absorbing the soluble food; whilst the absence of sufficient moisture creates a means for checking the flow of sufficient sap, at the same time as it limits the supply for rendering soluble the chemical constituents of the soil required to promote vegetative expansion.

It has been assumed in descriptions of the progress of Indian culture that by forcing the growth of cotton-trees to too great an extent by means of irrigation, exuberance of wood will be produced without a commensurate growth of flower and fruit. The supposition is not unreasonable, but it must have been created by continually observing the small cotton-shrubs grown in that country, and by not sufficiently taking into account the disadvantage of the shallow culture and imperfect irrigation carried on there.

In many of the American States the cotton-plant will attain before topping an altitude of eight or nine feet and upwards in one year, and yet it is from trees of this description that six or eight hundred pounds of merchantable cotton is sometimes obtained from each acre of land cultivated. The fact is, the cotton-tree is a quick-growing plant, provided all things conducive to its expansion are in accordance with the perfect progress of vegetation; but if any element, chemical or physical, is either absent, or remains in a state of quiescence, good results derivable from cultivation must not be expected; but as all conditions requisite for the attainment of agricultural perfection can be put in activity on any of the Indian soils, the want of future success will alone be caused by supine neglect in a quarter where it ought not to exist.

An enlarged growth of the branches and height of cotton-trees neither deteriorates the quality nor diminishes the quantity of wool produced; on the contrary, it indicates the perfection of the state of cultivation and the adaptation of all the conditions of the soil, either naturally existing or produced by tillage, to effect in conjunction with aqueous, aërial, and solar influences the largest amount of vegetable expansion the land is capable of giving.

The ultimate tissues of the roots (or parts last formed, called spongioles) cause the separation from the moisture contained in the soil of the elements requisite for the due formation of the plant; but all the elements contained in the moisture of the soil are not taken up, the action of the agency employed being limited to the combination of those elements in the proportionate quantitative requirement of each plant in the due promotion of its growth, varied, of course, by season. This discriminating power of plants, if it may be so termed, is called the assimilation of elements required to form sap; and although the results of the law which governs this action may be observed and directed to a beneficial end, a further knowledge of the law itself lies perhaps beyond the reach of the human mind to comprehend.

In addition to the power of the root to select, prepare, and take up food, it possesses the faculty of returning back to the soil a combined portion of the soluble organic and inorganic elements it has previously absorbed. This process constitutes the action of the exosmose of vegetation, or descending sap. The very quick growth of the cotton-plant seems to employ this faculty in a rapid manner; small, flossy, film-like cobwebs are often visible, and in contiguity to the roots of quick-growing plants.

The chemical condition of sap is again changed in respect to the nature of the soluble ingredients required to form flowers, fruits, and seeds; this second sap is derivable from the first, and consists of such elements as the flowers, fruits, and seeds may each respectively demand, the proportion of the elements being in a different ratio to that required for continuing the growth of trees, shrubs, or plants; in addition to which, solar heat and influence is indispensably required to concentrate the juices derived from the sap, and to store the result in moist productions, as in fruit. In drier bodies, as in seed and grain, or in the state of fibre accompanied by seed, as in cotton; but should the ground be too wet, either from the effects of heavy rain and want of being adequately drained. or from imperfect irrigation, the conditions for commencing and perfecting the growth of the flower, fruit, and seed would be disturbed, the sap would be too thin and poor, the solar heat and influence would be too deficient to effect the inspissation so indispensable for forming fruit, seed, or vegetable wool. Now, as the irrigation practised in India consists of a process of mere swamping the surface of the ground with water, in quantity often too large and at intervals of too great a separation, the tillage at the same time being too imperfect and shallow, it may easily be inferred, therefore, that the results of cultivation of this character will always be deficient, and the profits altogether unsatisfactory.*

* Plants will grow, but not vigorously, in soils which contain in solution too large a quantity of some particular fertilising matter. As, for instance, too great an amount of iron or common salt; but the effect of an excess on the healthful condition is soon made manifest by the loss of colour and the shrivelled appearance of the crop; and in the case of cotton-trees the result may be observed by the immediate attack which insects make on the vegetation. Large quantities of organic and inorganic matter may mix with the soil and no injury may result. As, for instance, crystallised and other limestone, iron in certain states, and vegetable matter, as humus particles or peat, may form a portion of the soil, but these substances are always in an insoluble condition; but if the iron is only in a slight degree soluble, its effects are perceived, springs and stagnant waters becoming chalybeate when in contiguity with such soils; draining the soils brings out the superabundance of deleterious matter, but irrigation water, if it passes through the ground, produces a still more rapid result. Nature is always endeavouring to restore by circulation the equability of soil so as to increase its vegetable producing power by carrying off those soluble elements which are in excess, and leaving behind by the act of irrigation, or dissolving out by the aid of rainfall water from the passive portions of the soil those elements which are deficient in quantity.

CHAPTER XVII.

ON CONVERTING BARREN SALINE LAND INTO AGRICULTURAL FARMS AND PLANTATIONS.

THE salting of the surface of land is a frequent occurrence in hot countries having but little annual rainfall, especially on those districts possessing too limited a supply of sweet water for irrigating purposes; but salting is still more common on wide stretches of country where rain-water is not drained out, but is left to re-evaporate from the surface on which it falls. But the cause of the salting of land is more especially due to the evaporation of water left on slight, shallow, and extended depressions of the ground. After the inundations have taken place, all the salts contained in the overflow water are left annually, and become visible after rapid evaporation caused by a bright sunshine, dry weather, and tropical heat has effected the dissipation of the water.

Particles of earth existing in a state almost fluviatile in the waters of the inundating river are deposited on the ground in slight films. This takes place after the water has lost the greatest part of its velocity on leaving the channel of the river, and the process going on year after year, the ground ultimately obtains an accession of rich soil, and an accumulation of buried salt, which rises to the surface of the ground with the subterranean water during hot parching weather and during the occurrence of much evaporation; this accounts for an excess of saline matter on the surface of the earth after the water to a considerable depth is dried out.

Great solar heat acting continuously on ground saturated with water near the surface, sucks up by capillary attraction and dissipates by evaporation the water contained in the soil, leaving the salts on the surface of the ground to an extent which retards the growth of useful vegetation, and often altogether interposes an insurmountable obstacle to successful cultivation. From the causes just now stated many districts of great extent in various parts of the world, naturally possessing cultural capabilities of surpassing fertility, remain barren deserts, because the means by which the conditions of such territories could be ameliorated are beyond the reach of individual cultivators; and the will, the knowledge, and the means of the respective governing powers owning and possessing these lands (being mostly Orientals), are never directed to an object so low as deriving wealth from the soil, or practically applying experience to that purpose, even though tillage would by that means be rendered both effective and most profitable.

Salt lands, such as are now under discussion, are situated on higher levels than the sea-coast salt marshes which have been before referred to; they exist as far north as Greece, Turkey, Spain, and Syria, along the African shores of the Mediterranean Sea. In most parts of Asia, and especially in various sections of the Indian Empire, the principal salt is muriate of soda; but combined with it there are other salts of considerable agricultural value, the chief of which are potash and nitre, the latter sometimes forming the predominant salt, and is collected from the surface of the land as a commercial product of great value; it is not, therefore, that the salt lands are of themselves infertile, but that particular salts are in excess, especially in those periods of dry weather which annually occur.

The state of all salt land is referable for its condition to the insufficiency of rainfall in the districts in which it is situated, and also to the want of deep drainage, by which the rainfall water might be made to percolate through the pores of the soil, and by that means carry off the superabundance of saline matter; but as all soils contaminated by a superabundance of salts are located in districts deficient in rainfall supply, it may be concluded that agriculturally such land is useless unless copiously irrigated and carefully deep drained, in the manner before recommended; but it must be observed, that if upon investigation it is found that an undue quantity of salt is contained at some depth in the soil, the drains will in that case require to be cut lower than usual. If these means are adopted in an efficient manner, the saline land will in one season only be converted into a state of complete fertility, and the subsequent attention required to maintain the land in this favourable state should be chiefly directed to the necessity of rapidly passing through the soil at considerable intervals a volume of sweet water, in addition to that required to support vegetation.

Saline lands, from their nature, show that when they are situated in countries where rain is infrequent, an increased proportionate number of growing days may be reckoned upon, so that two or three crops may be raised from the same ground in one season.

CHAPTER

ON THE HYGROMATIC AND THERMOMATIC STATE OF THE AIR AND SOILS, TOGETHER WITH CONSIDERATIONS RELATIVE TO THE EFFECT OF ATMOSPHERIC CHANGE ON COTTON CULTIVATION.

To fully comprehend the effect produced by atmospheric moisture on the growth of vegetation, it will be necessary to state in detail some of the facts which strongly bear upon the question; we may then apply these facts to such local circumstances as evidently exercise considerable influence on the progress and development of cotton production.

If we take a retrospective view of the geographical positions in which the cotton plants grow in a state of the greatest perfection, and where the most considerable commercial returns are made for the labour bestowed on cultivation, we shall find that the territory is situated either in the vicinity of the sea, or that the local atmospheric conditions are influenced by oceanic contiguity.*

Some countries where cotton is cultivated have a perennial rainfall more or less distributed, and are situated near the sea, as Demerara, Cayenne, the American cotton states at the head of the Gulf of Mexico, or on the borders of the Atlantic Ocean. The cotton lands situated along the coast of the Brazils, the island of Jamaica, and the Bahamas, are all contiguous to the sea, which exercises an influence on the growth of the plant, and in some cases for a considerable distance inland the effect of sea air is still felt.

The cotton grown in Europe is produced from land situated not far from the sea; the atmosphere which has passed over the Mediterranean continues, and in its course also over the inland cotton-bearing soil bordering on the Roumelian shores; some parts of the seaboard of Italy and the Greek islands, as well as the Granadian coast of Spain, are also situated within the influence of an atmosphere modified in its condition by vicinity to the sea.

In Egypt, although a rainless country, the wind blows steadily from the sea to the Delta nearly the whole year, but the air may relatively be considered dry.

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* The advantage of a small amount of saline matter being contained in the soil has before been dwelt upon, and need not be referred to again.

Now, it must be obvious that a certain degree of increased moisture is contained in the air which is equally dispersed over a vast extent of cotton territories by the daily progress of the atmosphere which has previously traversed the surface of the adjoining ocean, the temperatures of which, though high, are nearly in an unaltered state from one part of the year to the corresponding period of the next, and as air always holds in combination an amount of moisture equivalent to its temperature, if it is within reach (and it always is obtainable if long in contact with, and whilst sweeping over the surface of some contiguous ocean), so that at a temperature of eighty degrees the atmospherical moisture coming from the sea will probably amount from five to eight grains in weight of water to each cubic foot, but if the tropical atmospheric current at a time of great heat passed over the lower declivity of a mountain range, or had moved over a dry territory, the soil of which had to a great extent lost its moisture to a depth below the reach of capillarity, then the water diffused in the air most probably would be reduced to two grains of moisture to each cubic foot, consequently the exhaustion from the surface of vegetation would be increased in that proportion, at least from ten in the morning to five in the evening.

During sunshine, the air in contact with the earth is considerably more dense than the atmospheric stratums immediately above; nevertheless, moisture translates itself by the laws of affinity and diffusion through the intervening space from the heavier to the lighter elements. The moisture again descends when atmospheric heat is diminished by contact with cooler currents, or when the air is not acted on by direct solar heat: its molecules then becoming less separated by loss of heat, unite into particles and fall again by the force of gravity; it thereby forms dew on plants or deposits hydroscopic water, which the earth re-absorbs.

The temperature of the sea changes but little, and were it not for the intervention of currents it would always represent that mean thermomatic state of the air which belongs to each geographical position. That part of the atmosphere which has for some time been moving on the surface of the ocean soon assimilates in temperature with that of the sea; the moisture becomes nearly equal to the amount demanded by the complete saturation of the air, and when it leaves the sea and sweeps over the surface of contiguously dry land, the moisture, by the superior affinity which soils possess, is in part withdrawn from the air and absorbed into the ground at the rate of one hundred tons of water per acre during the course of one dry night.

It has before been observed that on the re-dissipation of absorbed water, as well as the diffusion of the water drawn to the surface-soil by capillarity, that an absorption of latent heat to the surface of the ground takes place; the absorption of this heat is the cause why the vegetative mean of the temperature in the cultivated soil is at all times during summer weather maintained. This growing mean of temperature in our climate may be considered to range as stated below:

		THERMOMETER.	
		April.	July.
Atmospheric temperature in shade, 12 o'clock in the day		60	70
Soil, fine dry loam	In sunshine	80	90
	Surface of vegetation	65	69
	Earth, 1 foot below grass	55	60
	Earth, 4 in depth	66	70
	„ 6 „	67	70
	„ 12 „	60	65
	„ 24* „	50	54

In the column representing the state of the subterranean heat for the month of April it will be perceived that the spring heat is slowly penetrating the ground; the surface temperature of the soil is subdued by the evaporisation of moisture from the surface. The July column indicates that although there is a considerable increase of penetrative heat to about three feet deep, yet the mean temperature of the earth is not disturbed. From this data it may be perceived that evaporation of the subterfluent water has exercised a considerable and important influence in maintaining constant equilibrium of temperature in the tillage soil.

The moisture contained in the upper surface of soils does not in any material degree differ in temperature from a thermometric monthly mean of their respective localities. Although dry surface-soil immediately exposed to the solar rays in the tropics will often receive and absorb heat of 120 deg. to 130 deg. where there is no subterfluent water rising by capillarity to counteract the absorption of so great a heat by the evaporative action of moisture, yet the water of rivers and quiescent water, that is to say, water in a stagnant state,—either in deep masses, or those waters which saturate the ground to an extent which excludes the air,—receives very slowly any increase of heat from the superincumbent atmosphere because the particles composing the surface water and receiving heat will become the lightest on account of expansion, consequently heat can only in a slight degree pass downward into the earth. Not so, however, in respect to heat descending when rainfall water penetrating the ground by infiltration, because it then carries through the soil a considerable portion of the warmth which was contained in the lower atmosphere, but which warmth, it must be observed, is no portion of the heat evolved by solar refraction.

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* At this depth it is the mean temperature of the earth.

The consequences of these alternate changes taking place in regard to water penetrating the ground in the state of rainfall, or leaving it as aqueous vapour (and especially as respects the effect produced on the ground by the interposition of evaporative action, required to restrain too large a proportion of descending heat from entering the cultivated soil), are questions of great moment when we are considering the methods by which nature sometimes, co-operatively with art, regulates and fits the temperature of the ground to suit the conditions requisite to keep the productiveness of vegetation in a state of the most vigorous and healthy progress. It is on this account that some labour has been bestowed in making an attempt to exemplify the operations of those physical laws by which the temperature of cultural ground is equalised and restrained within narrow limits from change.

Tropical plants cultivated on land not much higher than the sea level, evidently require for their due vegetative progress that the soil in which they grow should have a depth of from three to five feet of mean heat corresponding to the mean heat of the country in which they grow.* This may be called the subterranean growing temperature of the tillage-soil, or that part of the soil in which the roots seek for food, or, as it may more properly be called, the root-heat of the earth. If we except England, the following list will show the average temperature of bottom cultural heat of soils in several countries where cotton is raised:

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* Tropical cultivation requires constant reference to be made to the advantage of cooling the ground, whilst cultivation in the temperate zones is a continual effort to obtain subterranean warmth; both these efforts are directed to one end, namely, the maintenance of an equality of temperature in the soil at the root depth. The date-palm is an exemplification of this; the leaves exhaust and dissipate a vast amount of water, to obtain which, at a mean temperature, the roots descend through hot sand sometimes fifty feet and more in depth before the moisture is obtained, or its roots are sunk in a soil having a uniform temperature from the oceanic river or oceanic water levels. The temperature derived from the absorbed heat of cultivated ground has no analogy to the solar heat reflected from an arid soil, hence the burning heat of the one and the temperate heat of the other.

MEAN TEMPERATURE AT A DEPTH OF FOUR FEET OF CULTIVABLE EARTH IN THE FOLLOWING COUNTRIES:

		Degrees of Fahrenheit.	
	England	50 to 52	Summer. Dry loam.
	Delta of Egypt	68 „ 72	May. Irrigated land.
	Algeria (Oran)	60 „ 65	
United States.	Florida	65 „ 70	Sea level. Cotton plantation.
	Alabama	65 „ 68	Do.
	New Orleans	72	Do.
	Arkansas	60 „ 62	Eighty feet above the sea.
	Texas	75 „ 79	Fifty feet above the sea.
	Charleston	69	Level (marsh). Cotton land.
	Savannah	68	
	Mobile	72	Dry cotton land.
	Demerara	80	Drained land. Cotton plantation.
India.	Bombay	82	Very uncertain, land dried up one part of the year.
	Bengal	79	Uncertain, land dried up after monsoon.
	Madras	82	The same observation.

The above list indicates nearly the temperature which tillage-ground attains during the growth of cotton-plants; of course, in countries where the temperature is so high the surface-soil will absorb from mid-day sunshine more heat than that indicated, unless vegetation covers and shades the cultivated surface.

Before quitting the considerations connected with these details it will be necessary to make some reference to the evaporation and consequent cooling which emanates from the leaves of cotton-trees during daylight. This quantity cannot be taken at much less than one thousand five hundred tons of water consumed each season, and if the crop is vigorous it will amount to much more. This will give some notion of how far the ground will be cooled by the dispersion of so large a quantity of liquid in the state of vapour.

On the subject of the effect produced by the circulation of wind through the rows of cotton-trees growing on plantations, it may be necessary to state that the growth of vegetation is much increased, and the quality of sap much improved, by the circulation of gentle winds through and amongst foliage surfaces; by which means exhalation of water and the dispersion of oxygen from the stomata of the leaf is quickened; the supply of carbonic acid increases; the return of the sap and deposit of the food in the bark and vascular tissues is greatly expedited; to which may be added that by the too great proximity of plants, and too much interlacing of branches, lateral growth is diminished, the requisite continued movement of air is interrupted, and the solar ray is cut off. It is requisite, nevertheless, that the leaf surface be commensurate with the area occupied by the root and the dimensions of the stem; these conditions measure the force by which the vegetative elaboration is effected.

In order to preserve the healthful condition of cotton-plants, it is indispensable that sunshine be admitted upon the leaves and to a certain extent upon the ground also; unless sunshine falls upon every leaf and fresh volumes of air circulate through the foliage, the proper progressive growth cannot adequately proceed; for without sunshine the assimilation of carbon, oxygen, and nitrogen, which is only in active progress in the day, would remain quiescent, and the necessary increase of mid-day heat in the fluid of the sap would not take place. These conditions presuppose that the ground is kept cool by the evaporation of moisture, and that the requisite equilibrium in the temperature of the soil is thereby maintained.

In contradistinction to this, it is requisite to note that the American planter always recommends strenuously that every effort should be made to forward the cultivation of the cotton-plants, so as to get the ground covered and shaded as early as possible with interlocked foliage; whilst, on the other hand, up to this point, he as strenuously recommends all weeds and other obstruction to the solar penetration of heat being removed. The first object is promoted in the spring of the year, in order to obtain as much bottom heat for the use of the root of the plant as possible; and the next object he has in view is directed to the attainment of as much shade over the ground as possible, by which means too rapid an evaporation of the water from the soil during summer heat is diminished. But it must be observed that all the recommendations which have been made relative to cultivation have had reference to lands requiring water to be applied artificially and in varying quantities during dry seasons, so that precautions in respect to evaporation of moisture from the surface of the ground are less to be regarded.

The Demerara planter, on the other hand, has nothing to fear on account of excessive evaporation; because on all sides of his beds there are channels continually charged with water, which by subterfluent action always keeps the ground wet at from three to five feet deep, according to the nature of the soil. The moisture comes to the surface by capillarity in sufficient quantity to keep it moist; and therefore he is enabled to grow the trees sufficiently apart to allow the air to circulate freely. The Demerara cotton-plants are perennial, whilst the American planter's trees are only annual, because the frost destroys them immediately after the autumn. The American planter also depends for moisture upon the rains, which, although copious, are not heavy; on this account he always, except near the coast, seeks for moist bottoms and loamy soils of considerable depth, and having great capacity for retaining water; but although his best crops are obtained in seasons of great sunshine, nevertheless his experience leads him to prefer shading the ground and thereby retaining moisture, although it requires the relinquishment of the great advantages of copious air, circulation, and adequate sunshine.

There are two systems of planting much connected with the question which relates to this division of the subject, and requiring separate considerations. It is well known that the Mississippi planters lay off their rows at about four to five feet, and in rich alluvial drained land six or seven feet; each tree in the row has also a space between them of eighteen to thirty-six inches. Now, supposing the trees to be five by two feet apart, then four thousand four hundred trees would stand upon one acre. It is also known that the West Indian planter frequently places trees in hills, that is to say, little mounds are drawn up by the hoe towards the stem, the trees being each spaced so that the alleys are open in both directions. By this system, if five feet is left between each tree, then only one thousand seven hundred and sixty trees will grow on each acre. But in the case of biennial or perennial plants, lateral extension of wood will take place to a degree quite equivalent to the diminished number of trees; but a still greater advantage will be found in the increase of sunshine and air circulation in every direction, which will follow the adoption of this system of free openings; in addition to which, the cotton-picking can be carried on much more cleanly and expeditiously.

The great advantage this system possesses will be found in the tillage department. After the trees are pruned (almost entirely cut away), the ground will be then quite open for the plough to operate both ways, that is, both in length and breadth across the field, as well as for all tillage process, until the growth of new shoots prevents horse husbandry being carried on further. This course of husbandry will of necessity be limited to those situations where there is but little necessity for open drains to be left, but if the works of irrigation are numerous, the close-row system must alone be followed.

It will be desirable to make some reference to two countries I am well acquainted with—namely, Demerara and Egypt—in order to meet a suggestion made, to the effect that too much moisture existing in the air was injurious to the growth and quality of cotton. Now, Egypt is altogether a rainless country, the evaporation is excessive—amounting to one quarter, and frequently exceeding half an inch per day—whilst in Demerara, in one half of the driest part of the year, there is as great a rainfall as occurs in the whole year in England. The total annual rainfall is ninety inches, the coast evaporation is limited to thirty inches, being an amount less than that of most parts of the low-lying lands of this country. It is from these facts quite clear that the Demerara coast, which is one of the cotton regions of that part of the world, is moist, although there is much sunshine and a very uniform heat (seventy-eight degrees Fahrenheit); nevertheless, very large deposition of moisture occurs at night, the thermometer being then very much lower. On the other hand, in Egypt the cotton plant grows, flowers, and bears fruit without ever coming in contact with rain; hence, so far as either moisture or dry atmosphere is concerned, no detracting effect is produced in either country; the only conditions common to each is their contiguity to the sea, saline-mud deposits, equality of temperature nearly throughout the whole year, and their maritime climates, which in both cases exercise a favourable influence over the conditions required to bring the cotton-plant to perfection. It has been pointed out before that the chief regions where this plant is grown to the largest extent, are so situated that atmospheric currents, tempered by a warm and often a tranquil sea, spreads over them, and thereby maintains an equability of climate which is essential to the growth of vegetable structures like cotton-trees. This is exemplified in the largest manner by studying the physical geography of the cotton region of Guiana and Texas; and if the position of the Southern American States be taken into account, as far as relates to their contiguity with the ocean, it will be seen that wherever the air which has been in contact with a sea is of a temperature higher than that of the land, and has spread over the contiguous territories (and supposing the agricultural conditions of the soil are favourable), good results from cultivation always follows.

In more northern countries, and for the raising other products, this rule holds good; for instance, the coasts of Spain, Portugal, and France, as well as the south-east coast of Cornwall, have a climatic fertility superior to those districts situated in the same latitude, but farther inland.

Now, as the coasts of India partake of these characteristics in an eminent degree, and as many exclusive territories have only a limited rainfall—for instance, Bombay, Madras, from Cape Comorin northward, and the Delta of the Indus and parts of Bombay, and in which countries a large period of the year would be growing days—it is clear that on the sea-coasts of this vast empire all the united conditions which I have endeavoured to explain as being necessary for cotton production may be found.

APPENDIX.

THE COMMERCIAL TRANSIT BETWEEN ENGLAND AND INDIA THROUGH EGYPT.

If an examination be made of the cost of growing cotton in India, in quantity and of quality and value equal to that of America or the Brazils, the comparison is interfered with when the increased amount to be paid for freight to England from the former countries is taken into account. The distance from India to England by the Cape, as compared with the distance from New Orleans to England, being as 5 is to 11; but if the commercial transit track traversing the Red Sea and passing through Egypt from the same measuring point, namely, Cape de Galle, be taken, and supposing all other circumstances to be equal, the cost would be only as 5 is to 6, leaving only one-sixth of the distance in favour of shipments made from New Orleans to England, as compared with freights from India.

But other things are not equal; there are present difficulties in the navigation of the Red Sea, owing to the want of beacons, buoys, lights, and the absence of a supply of fresh water. The arrangements of the railway traffic across Egypt creates the necessity of transferring the cargo at Suez to the railway by hand labour and by small boats, and then re-transferring the same cargo at Alexandria to another ship in the same manner, and *vice versâ*, for goods coming from Europe.

The railway of Egypt itself is inefficient for the commercial purpose of an extensive cargo transit; the division lying between Cairo and Suez is located on a rising summit—upwards of five hundred feet—and to surmount this acclivity all the water required by the locomotive engines for performing the journey to Suez and back is taken from the Nile at Cairo by special water trains; in addition to which the line is only a single track, and does not at either end communicate with the shipping. The roadstead at Suez is some distance from the railway terminus, the only communication being effected by small boats; the conveniences of coal staiths, watering stations, wharves, warehouses, lighthouses, docks, or slips being entirely unknown. At the harbour of Alexandria something better might have been expected; but here the want is the same as at Suez. The coal which arrives from England for the use of the vessels engaged in the postal transit is all landed from ships in the harbour by small craft and re-shipped again in the same manner to the steam-ships, unless a vessel should opportunely arrive so as to be put at once alongside. The port of Alexandria has no docks, deep-water wharves, or depôts worth notice for the convenience of landing or discharging cargoes; all has to be done in little, mixed up with delays, at great cost, and, except through the hands of one company, no commerce passes in this direction. The coal required for the steam-ships arriving at Suez, Aden, Bombay, and Point de Galle is all sent round by the Cape of Good Hope, which increases the travelling distance of this indispensable article to Suez, as compared with a direct transit, as 12 is to 3, added to which the great difficulty experienced by sailing-ships in contending against the almost constant north wind in the unlighted Red Sea is so great, that distance might fairly be estimated in loss of time and other detracting circumstances as 18 is to 3, compared with the direct route. It is questionable if the present Red Sea traffic could be sustained without a bounty from the British Government; but if the contemplated traffic arrangements were completed to the full extent, no aid from Government would be required.

The railway has no adequate rolling-stock for commercial transit even of a limited extent placed upon it, consequently, except some few cargoes of silk conveyed by the company alluded to, no commerce passes in this direction (if we except the limited amount demanded by the postal requirements for India and a portion of the passengers proceeding and returning from Australia, China, India, and Mauritius). The company, possessing the whole traffic in this direction, think the present means and appliances sufficient, and certainly they ought, and no doubt are, satisfied with their present profits.

Notwithstanding dissatisfaction may be expressed at the omission to make complete the railway and marine constructions so much required at both the Alexandria and Suez end of the Egyptian transit, yet all Europe must admit that vast good has accrued to several nations, and to England especially, from what has been so far accomplished, and that it is owing to the liberality of his Highness Mehemet Pacha for commencing, and to his Highness the present Viceroy for completing and continuing, sometimes under adverse circumstances, the railway passage through Egypt.

From what has been said, some judgment may be formed of the great necessity which exists for further works being constructed and a larger amount of rolling-stock being employed, as well as a considerable number of properly-devised steam-ships being placed on the marine track from Suez to India, so as to materially lessen the present cost of transit and freight, and thereby cause a considerable amount of the commerce between India and Europe to take this direction; for the fact must be kept in view, that abridging the distance between Europe and India, China, and all Eastern territories, is one of the great questions invoking most serious consideration.

It may be assumed that the great canal designed by M. Lesseps for facilitating the passage of the largest ship through the Isthmus without lockage, will answer all the purpose required. Now, although I have been over the whole line of this proposed canal, and have examined the intended outlets both at Manzella on the Mediterranean side and Suez on the Arabian side, I am not prepared to say one word in disparagement of the undertaking, or make observation relative thereto, except so far as stating that, according to my view, it appears to be a work the benefit derivable from which must be received, in the natural course of things, at a long protracted period, and perhaps by a succeeding generation, whilst the necessity of this communication being thrown open for the benefit of all European nations is demanded by present exigencies, and at once. It is no presumption to say that the whole transit both by sea and land might be perfected and brought into full action in a period much less than is required to collect the materials alone necessary for constructing either of the harbours indispensable to make the canal efficient.

The harbour of Alexandria having only a tide of two to four feet, its water for all practicable purposes may be considered in the character of a floating dock of vast size. This circumstance offers great advantage in the formation of quays for the largest ships to be placed alongside to take in or discharge their cargoes; and for this purpose there are also good situations, having at all times quiet water, and in every respect well calculated for forming miles of deep-water quays, easily connected with the railway. On these quays staiths for loading and unloading ships by hydraulic cranes could be erected, so as to clear and transfer the cargoes in the shortest time and at the least possible expense into the railway trucks; with the quays could also be connected with warehouses for the reception of grain, silk, teas, cotton, and other produce, forming the return cargoes for the ships bringing coals and European manufactures.

The existing line of railway from Alexandria to Benna would require to be doubled, the present being only a single line; but the beautiful and substantial bridges over the two branches of the Nile, constructed by Mr. Stephenson, are in all respects adequate to any traffic, however large, it may hereafter become.

From Benna a new double line without summit is required to be formed, extending to a distance of four miles beyond Suez. This extra distance will join with the banks of the Red Sea in the Gulf of Suez, on its western shore, at a locality in every way fitted to be the site of a new town and port; so well adapted by nature is this locality, and so favourably situated, that a large roadstead already exists, having sufficient water close up to the shore, and excellent materials may be quarried close at hand for forming an extensive range of deep-water quays, where the largest ships could either load or discharge their cargoes. Behind this site, at a distance of five miles westward, there is a range of mountains, which, from their elevation, sometimes bring down heavy falls of rain. The gorges of these mountains indicate by erosion the effect and pressure of floods; but none of the torrents periodically formed ever reach the sea-coast because the ground being exceedingly dry, the water in a short distance is entirely absorbed in the sand. From all these circumstances I arrive at the conclusion that any amount of sweet water will be found by sinking in the porous rock at the foot of these mountains; and should such be the case, it would exercise a great and beneficial effect in promoting the establishment of any community actively connected with the commerce of the eastern transit.

There are wells of water connected with subterranean springs situate three miles from Suez, on the Syrian side of the Gulf, having a considerable brackish taste, but which saline character is derivable from the upper salt crust which entirely covers all the plains near the sea-level hereabout; but if iron cylinders were sunk into the water-bearing stratum, the superficial salt springs would be cut off, the subterranean water would then be quite sweet, and, from the nature of the springs and the situation of the adjoining mountains, I know that any quantity of good water might be obtained. I mention this because I am satisfied that at some period Suez must be a great commercial port; and as at this time its five thousand inhabitants have their only supply of water transported in skins by camels from these wells, of course no vegetable produce is raised, nor can the ships obtain any: all the vegetation consumed requires to be brought from a distant country, lying within the influence of the Nile irrigation; the soil of the plains round Suez being calcareous and rich in the ingredients of fertility, require nothing but an abundant application of water to divest them of their superfluity of saline matter, and to render them fruitful in the extreme. And I need not dwell on the advantage that might be derived from the attainment of water for local cultivation of the soil in the neighbourhood of a sea-port distant eighty-four miles either from any other town or the vicinage of cultivated land; nor need I remark how much the Isthmus transit is dependent on water supply, especially when it is noted that the trains leaving Suez entirely rely on the arrival of other trains bringing the required water from Cairo for locomotive use.

The new line of railway would leave Mr. Stephenson's line at the Bridge of Benna, and run in an eastern direction across part of the Delta, to the valley at the entrance of which are the villages of Habesek and Messar, both on the borders of the desert, and then taking the line of Onade Tomlat (being the line of the ancient canal from the Nile at El Moez to Suez), and would pass by the ancient ruins of Aboakectreid, after which it would turn in a southern direction, passing by the borders of the dried-up salt lakes, and keeping in the wide valley which leads to Suez. This line would pass over a country quite level, unintersected with lateral valleys, free from all obstruction, and capable of self-supplying the water required for locomotive use for three-fourths of the distance from the Nile.

For the purpose of rendering the Red Sea more easy of navigation than any other known sea it will be requisite to light the headlands, to beacon the outer ends of the coral reefs, and to lay down buoys in the Gulf of Suez.

The Red Sea is a mundane fish-preserve, from which all Europe might, at a very small comparative cost, be supplied with guano, prepared and desiccated by the powerful heat of the sun and the exceeding dry state of the air, thereby producing at the cheapest rate one of the richest fertilizers known. But to accomplish this the commercial passage across the Isthmus must be rendered available by the adoption of all requisites for establishing the cheapest transit of goods.

At Aden, no other convenience is required than that of erecting deep-water wharves and coal warehouses, and the construction of coal staiths, for the quick despatch of all the operations connected with unloading ships and re-coaling the vessels engaged in the Red Sea traffic.

Circumstances are not so favourable at Cape de

Galle, the harbour of which place, however, is advantageously situated in a geographical sense, but it lies open to the sea, and has no dock or other adequate provision for carrying on any of the operations connected with the economical transference of cargoes; all these are the more wanting, because this is and must always remain a great commercial collecting point, and perhaps no place could be found where the facilities and materials for the construction of a good harbour more abundantly exists. On the north side, the natural ledge of granite rocks points out the place where the most enduring foundation for a breakwater may be rested upon; in fact, the rocks lie so favourably in form, that the space between them in their natural positions only require to be filled up, an abundant supply of granite for the purpose may be had within two miles of the harbour by constructing a railway along the sea face of the fort.

On the south side of the harbour entrance a more extended work is required; but it would not be needful to connect it with the mainland on the southern shore. A length of one quarter of a mile (to begin with) of breakwater—in addition to the work before alluded to on the north side—and having an overlap entrance, would make this harbour not only a secure place for the commerce connected with all India, but a refuge for sheltering during stress of weather the number of ships, large and small, which navigate the contiguous waters.

The steam-ships now employed in this tropical division of the world, are all constructed on the same principle as ships employed to navigate the Baltic, or other northern oceans, and have little reference to climate or the altered condition resulting from tropical heat; in fact, some of them have been constructed for the performance of the Bay of Biscay voyages, and the ships which navigate the Red Sea have the same top hamper and rigging as though they were about to commence a voyage to the American coast, or were liable to meet the gales occurring about the great banks of Newfoundland. An inspection of the native vessels now navigating the Red Sea, indicates that no severe weather is ever expected; they are mere shells of the most worthless design, and weak in all respects and inferior in workmanship; in fact, from Aden to Suez, there is no native vessel which would live in a northern breeze for one hour; all these vessels are undecked, except for a short space fore and aft; they proceed to sea without pumps or compass, and have only wooden anchors to bring them up; it is therefore evident that for the navigation of this sea a differently constructed vessel is required; not in respect to strength as compared to the present steam-ships (but having regard to the peculiarity of climate), the arrangement of the propelling power, expenditure of fuel, and other circumstances which bear so strongly on the expense of transit, either as regards goods or persons, passing along this route.

The transit from England or other parts of Europe to Alexandria requires no especial provision to be made as to the nature of the ships employed, or their accommodation. This seaport is even now a great collecting centre from many countries; and if the facility for transport across the Isthmus was made as perfect as its great capability permits, no person can either by computation or foresight arrive at a correct conclusion which would represent the future traffic in this direction; therefore, the division of the Egyptio-Indian voyage as far as it relates to the traffic between Alexandria and Europe, ought to be left to competition, and to the co-operation of those associations which would work correspondently with the lines of the Red Sea and the Eastern traffic in such a manner as may hereafter be established.

Connected with the economy of the commercial transit there is a subject of great importance, having relation to the waste in the calorific power of coals whilst stored in various sea-ports to await the arrrival of steam-ships. It is known that a considerable portion of the gaseous element contained in coals are easily dissipated by contact with dry air; and the atmospheric affinity for these gases is further increased in a considerable degree by the great absorption of solar heat and the ensuing desiccated state of the air; now, as coals taken at an immense cost to the Red Sea and India are placed at their destination in open-sided depôts until they are required, the consequence is that their calorific power is greatly diminished, the separated particles are exceedingly annoying both to firemen and others, much breakage takes place, and altogether the cost of the ton of coals does not represent the duty done. To remedy this unfavourable condition of a very costly item of transit expenditure, the coals should be placed in depôts built with great thickness of wall and roofed with earth, the walls should have as few openings in them as possible, and they should always be closed, except at needful times.

In these depôts sprays of water should be kept in constant action by some applied mechanical force, the air would then become very moist, and that circumstance combined with the cooling power due to evaporation, would in a considerable degree reduce the temperature, and the waste caused by the dissipation of the gas would then cease; in fact, the coals would come from the depôt as moist and fresh as when taken from the pit. Salt water will answer the purpose for forming the sprays, but must be frequently changed, or rapid evaporation will cause its conversion into strong brine; and precaution should be made for preventing any salt water falling on the coals.

The passenger ships which should be placed on the line of transit between Suez and Aden ought to be propelled by paddle-wheels of large diameter; the engines should be placed amidships in an open space, without other shelter than that of a woven wire or other awning to resist the excessive sunshine; the engines should have a long stroke, and the steam high-pressure, worked expansively, to which should be added every means for properly superheating it to a judicious extent. The vessel should have a broad beam and light draught of water; the cargo should occupy all the space below, except that required by the engines; the quarters of ship's crew and officers, together with the space assigned to passengers, should be located on and above the principal deck and not below. A vessel of this description would (except in strength, workmanship, and details) be in some degree like the ships which traverse the Ohio and Mississippi rivers.

If this route was opened for goods traffic the passenger traffic could be more distributed in each ship; and although these vessels would not, perhaps, make the same speed as those now employed on the existing passenger transit, yet the diminished charge and the greater space allowed to each passenger, would make an adequate compensation for any extra time consumed.

For the purpose of navigating the Red Sea, the masts should be so constructed that they would have joints, and be otherwise made capable of being lowered into crutches above the deck; there would be no necessity for using shrouds or stays if the mechanical arrangements are correctly designed. Consequently, the top hamper would be lessened in weight and quantity, and the resistance of the air during the navigating northward would be reduced to a minimum amount. On the return voyage to Aden, the masts would be raised in a few hours; but after all, it is quite questionable if steam vessels on these waters would not make much better voyages without masts or rigging.

For the voyage between Point de Galle and Aden, there requires no special provision, except that demanded to facilitate the change of vessels at the latter place on such occasions as when ships carry passengers: this change would be a great boon; because for some time after and during coaling at Aden, the vessels are always in a most inconvenient state, and entirely unfitted for some days to be the residence of travellers, especially females and children; the inconvenience of changing luggage might by good arrangement be rendered expeditious, and the time consumed can be diminished to six hours, whilst it now requires twelve or fourteen for coaling.

The merchandise vessels plying between Suez and Point de Galle should be built like ordinary paddle steam-ships, but they should have larger wheels than any of those which now navigate the India Ocean, and should have also the facility of lowering the top hamper when the wind heads their course; but if the arrangements were made at Aden for loading and discharging cargo as has been before described (especially in many cases when the cargo is composed of bale goods and not of great value), a transference could with advantage be made to sailing-ships, especially when the great distance from the supply of fuel is considered—but, as respects Red Sea double voyages, no sailing cargo-ship could compete with steam-ships placed on that ocean, provided they are adapted in all respects to the specialities of that sea.

It may be surmised that discharging and taking in cargo twice, or, as before suggested, three times, would be both costly and inconvenient, and subject to loss and breakage.

At first sight, this view of the question seems to indicate that there are reasons sufficiently numerous to justify a conclusion that this route will never become the great line of transit for any considerable part of the heavy portion of the commerce existing between the Eastern nations and Europe.

Now, if all these improvements and changes in the several sea-ports before spoken of were established, and the railway lines in Egypt were rendered completely effective, and ships adapted to navigate the Red Sea were placed upon that part of the line of traffic, there would only then remain the question of transhipment, its cost and inconvenience, to be dealt with.

On inquiry made at Liverpool some years since relative to the cost of discharging a cargo, it appeared to amount to about twelvepence per ton on the average of a cotton, or other cargo of a similar kind, and the detention for this purpose of a six hundred ton ship, would be about from four to six days; this would make the utmost limit of detention twenty days on the total voyage, and the cost of four transfers, that is to say, the cost of putting in cargo as well as taking it out, amount altogether to five shillings per ton. But as the sea to be traversed is for its greatest distance much quieter than any other known sea, with very constant breezes occurring, there would be from ten to twenty days of advantage in respect to fine weather to be set off on the other side against the detention.

Now, in regard to the facility of transfering cargoes, it must be borne in mind that nearly all goods sent from India or China are packed in such a manner as to expedite their movement (this packing is often necessary for the convenience of furthering the merchandise from the interior of the country producing it to place of shipment); and as all vessels arriving with cargo would be placed on one side of a deep-water projecting pier, and a vessel intended to receive cargo would be placed on the other side of the same pier, the transference would be effected by self-acting hydraulic cranes, from vessel to vessel, without any other wharfing of the goods, except in such exceptional cases as when a vessel was from unforeseen cause not prepared to take a cargo in sufficient time to continue uninterruptedly the correspondence of transit.

In hot climates, and for the purpose of facilitating a traffic of this description, nothing would more tend to the rapid transference of cargo from ship to warehouse, or from warehouse to ship, or from ship to ship, than having the decks of vessels so constructed that a large portion of the centre might be entirely removable; by this means the wharf-cranes would act at all times nearly in a direct manner upon the cargo to be shifted, thereby saving a large amount of manual labour now required to unload closely-decked vessels. A ship so arranged would, in fact, whilst loading, be much like those Arab and other vessels which now make voyages over a large portion of the Eastern waters, open both to light and air down to the keel.

The powerful self-acting cranes which must necessarily be employed in large transactions of the nature of a vast transit would at once (assuming the vessel has been properly constructed) remove all the coverings of the cargo. These movable portions of the deck (too large to be called hatchways) could be transferred by other travelling cranes to some distance from the ship during the operations of either loading or unloading, and when the stowage was complete, be again placed in their positions in the ships by the same means and with the same facility as that of removal.

If the arrangement for facilitating the movements of cargo in all the ports now under consideration were carried into effect, if the vessels employed had their adaptability well considered before their construction was commenced, if the timing of the transit of all these vessels insured strict correspondence in their arrival and departure, then voyages could be made from Cape de Galle to England and back in as quick a time, and at as small an expense, as it now costs in time and money to make the voyage between New Orleans and England. This result is attainable because of the greater equability of the winds which are met with in a voyage by the Egyptian route as compared with a voyage by the Cape. No reasoning on the question need be adduced in favour of effectively opening this natural passage of commerce. The extreme distance of the voyage by the Cape, the delay from strong, contrary, and sometimes stormy winds, and not unfrequent calms, superadded to the unemployed capital involved in the value of the cargo during the time it is afloat, and the greater sea-risk, partly caused by the longer voyage, furnishes alone sufficient data for concluding that the great highway directly connecting and linking Europe to the East is in this direction.

The cost of bringing a cargo of cotton or other produce of a similar character from America or India to England is difficult to ascertain, because many extraneous considerations demand a position in the estimate; for instance, cotton sent from America may be sometimes considered as a return cargo, the profitable freight being realised from the cargo of English productions exported to that country, whilst, on the contrary, the cargo to India is composed, in general, of some English manufactures, a large part of which is only accounted as the requisite ballast, the profit being sought for in carrying back the greater amount of Indian and other Eastern productions required in the European markets; but should improvements in culture be introduced into India, and the advantage of an extended circulation of capital be thereby created, then the demand for European production will be so much increased that the freight will be as profitable from England as that derivable from the imported cargo. The realisation of this state of circumstances would at all times be most advantageous, because an equality of cargo both ways tends, in an eminent degree, to lower the cost of freight either way; this has been exemplified by the increase of outward traffic in the last few years, caused by the exportation of such materials to India as were required for the railways which have and are now being constructed in that country.

But since the realisation of the good effect derivable from increased cultivation and exportation is not yet brought into existence, a comparison of expense of freight either from India or America to England must be based on things as they now are, or rather as they recently were. It must at all times be borne in mind that any increase in cost of transport to the place of consumption must be deducted from the profit derivable from cultivation. I make this observation because I do not see that those who have advocated the cultivation of cotton in India have taken the present cost of transport by sea sufficiently into their calculation as one of the elements of the cost of production; but a just estimate of all the contingencies connected with a comparison of advantages or disadvantages appertaining to the production of cotton, or other produce in any country, must also include this element of cost.

The correct way of contrasting the expense of transit from India to Europe with the cost of the transit of similar cargoes from America appears to be by taking the mileage passed over as the standard of comparison, assuming, at the same time, that the cost of transhipment to be equivalent to the loss sustained on the Cape voyage by reason of the occurrence of calms in the tropics and extra insurance on the longer distance, there would then only remain the railway charges to be placed against the Egyptian transit, together with the payment to be made for dues arising from the passage of goods over the Egyptian territory. Assuming this latter charge to be equitably adjusted with his Highness the Pacha, and that the railway was put on the same footing as that of an European railway, the cost of the transit of goods from ship's side at Suez to ship's side in Alexandria ought not to exceed 1*l.* per ton, including all charges and dues. This sum must be placed against the Egyptian transit; but in diminution of this an amount must be placed for interest on the value of the cargo during the three or four months extra time consumed in making the voyage round the Cape of Good Hope. This amount may be taken at 10s. per ton at least; so that every cost, mile for mile, may be assumed as the same either way, if 10s. per ton be added to the mileage charge by the Egyptian route.

It may be thought that the voyage northward up the Red Sea, being performed by steam, together with the great cost of coals in that sea and in the Indian Ocean, may cause the transit through Egypt to be more costly, mile for mile, than round the Cape of Good Hope; but when the great equability of the winds and their favourable state at all periods of the year for facilitating the movements of navigation is taken into account, the cost of steam-power up the Red Sea will be amply repaid by the superior despatch in effecting the voyage; and in regard to the great cost of fuel in the Indian and Red Sea oceans, it must be recollected that opening this route for general merchandise will, in a most material degree, also diminish this expense, and in a larger proportion at Suez.

	Miles.
The distance from England to Calcutta, by the Cape, and according to the usual route of sailing ships, is	13,000
From England, by Gibraltar, Egypt, and the Red Sea	8,000
Saving in distance either to or from Calcutta	5,000
From England by the Cape to Bombay . .	11,500
By the Egyptian route	6,200
Gain in distance to or from Bombay . . .	5,300

From the above computation of distances we may ascertain the cost of freight either way. For example:

Take the freight from Calcutta to London at per ton				£4	12	0
Then eight-thirteenths of that amount would be	£2	16	7			
To which add the extra cost .	0	10	0			
				3	6	7
				£1	5	5

The computed cost of freight by the two routes will be found, namely, 3*l.* 6s. 7d.; which, deducted from 4*l.* 12s., leaves 1*l.* 5s. 5d. saved on the freight of every ton of goods either going to or returning from the East.

The above estimate is based on merchandise like cotton, 1500 lbs. representing a ton; but upon more valuable cargoes, such as tea, silk, indigo, &c., a greater rate of saving will be effected, and a stronger inducement will exist for using the Egyptian transit, because capital will be employed a much shorter period; of course lessening the cost of freight to and from India will depend on carrying out the improvements in the various ports I have referred to before. Unless those improvements are put in action in their full integrity it would be useless to look for commercial traffic taking this direction.

The cost of these works, with adequate rolling stock (and exclusive of ships), would be 2,840,000*l.* The interest, at 10 per cent., would be 280,000*l.*; and if 200,000*l.* be added for working expenses, there would be required an amount of transit equal to 500,000 tons, or say 250,000 tons each way, to pay for the outlay. This amount of tonnage is very small compared to the now existing trade with India, to say nothing of the future extension of commercial intercourse which inevitably must ensue on a diminished distance being effected between India and Europe. In fact, it may be stated that the value of all the Eastern possessions, whether French, Dutch, Spanish, Portuguese, or English, will be increased in a value proportioned as the distance is diminished by the establishment of a perfect system of intercommunication through Egypt.

An auxiliary benefit will also accrue by opening the Red Sea communication to Europe, either by the canal of M. Lesseps, or by the improvements in the various harbours and the establishment of the railway across the Isthmus, which I have described, or by the use of both these means, by which Arabia and the north-east of Africa will possess free intercourse, and the natural products of these countries may be cheaply brought to Europe, amongst which the vast amount of fish which may be dried and brought from the Red Sea, could be furnished to Europe at a cheap rate, which would equal guano of the first quality: it is not too much to say that 200,000 or 300,000 tons per annum could be most easily obtained, the supply being limitless.

It may be thought by some persons that the jealousy of the European powers may prevent the improvements across Egypt from ever being perfected; but, if the necessity which exists for cheap communication between all parts of Europe and the Eastern nations, the beneficial results which each would receive from being brought nearer to their transmarine possessions, or of more readily and quickly obtaining their required tropical productions, be taken into account, one is almost led to believe that each interested European state would contribute a proportionate amount of the means required for perfecting this great commercial duct, rather than allow the fear of realising remote and perhaps improbable events from keeping the bar undrawn from one of the natural portals of the world, and by which the industrial population of Europe are divided from the myriads of people composing the Oriental nations.

From the advocacy I make of the great advantage which Europe would derive from opening the passage across the Delta of Egypt, for the general commerce with the Eastern territories, it may be thought I do not give sufficient consideration to the work now in progress intended to effect this object, and on which M. Lesseps is now actively engaged. Without in the slightest degree undervaluing that work, I am compelled to look at the cost of great seaports which will have to be constructed in connexion with it, especially the one in the Mediterranean sea. I must also take into account the vast amount of work to be done, and the long period which will elapse before the canal can be rendered efficient; and again, that to navigate with the greatest economy and despatch speciality of purpose is required to be observed in the construction of the vessels employed on certain divisions of this route, in addition to which, if the system described was adopted, the saving in the time of commencing the operations of transit would be so great that all the cost of the works may be repaid back from the profits long before the canal can be completed; and even if the canal and the waggon transit co-exist, even then the traffic in this direction will by that time have become so large that the two systems would be fully occupied in transferring it.

Throughout this division of the report I have endeavoured to set forth the capabilities of Egypt and its susceptibility of improvement in an agricultural point of view; I have also drawn attention to its capability (derived from nature) of affording the means by which the great road to the southern hemisphere may be opened. In all this it may be thought that I place an undue value on the position of Egypt, either to concede the land for agriculture, to guarantee the rights of occupation, or to permit foreign interference in the transaction of that commerce which is connected with the transit of merchandise across her soil. I must acknowledge that to view these questions as connected with the interests of one European nation only, no encouraging aspect could be chosen from which a favourable conclusion could be made; but, if the question is freed from all political considerations and individual selfishness, we must agree that a Prince who has shown in his time the same disposition as was evinced in that of his Father for the introduction of improvement in his territory, should be guaranteed the sovereign right and guardianship of the pass by which the Eastern journey is made, and in return the necessary works for effecting the transit should be effected by European capital. The right of purchasing and cultivating the land accorded, the export duty on agricultural productions diminished, the transit dues regulated, and the right of European settlers so adjusted that their position should harmonise with the usages of civilised nations, then might be produced in Egypt at least one-third of the cotton required in the European market, and India, China, the English, French, Spanish, Dutch, and Portuguese possessions in the southern hemisphere would, in reference to time, be brought nearer by one-half the distance to their respective sovereignties.

I cannot conclude this part of the subject without stating that on three several occasions I have visited Egypt, and having in every part of the country made the most minute investigation into all circumstances connected with its further capability for agricultural improvement and extension; I may state that these observations and surveys were made not to gratify that curiosity which this wonderful country naturally excites, but as an experienced engineer who has long been connected with great works; and the conclusion I come to is this: of all the countries which I have seen in the four quarters of the globe, Egypt is the most capable of giving the largest agricultural results with the smallest degree of effort, it is the least liable to be effected by the countervailing influences of atmospheric change, its copious streams may be converted into direct wealth, every square yard of the Delta is capable of yielding several most bountiful harvests each year, and for the purpose of attaining a perfect transit of merchandise by rail from sea to sea, a road can be made so nearly level that no point will rise more than thirty feet above the sea; a country so connected as this now is with the northern world, must inevitably receive in future the impress of civilisation, and become awakened to the reality and advantages of industrial profit. Let us never forget that it was in this territory learning and the arts first had their birth; and we may hope that, uncoveted by any other nation, and protected by all, arts, learning, and industry may eventually return to their native soil.

THE END.

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COTTON TREE

SHEWING THE TAP & LATERAL ROOTS WHEN WELL CULTIVATED

H-

SCALE

The curved line D to E is the limit of the root of the American Cotton plant because the ploughing is not of sufficient depth the ground is not pulverised more than [illegible] inches below the surface C

F [illegible] of the depth of ploughing 3 Inches

G Indian or Cotton State

Dimension Cultivation

H

I Depth of Proposed Cultivation

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